Iron and Steel Engineer

Established 1907 as Proceedings of A. I. & S. E. E.

J. F. KELLY, Editor

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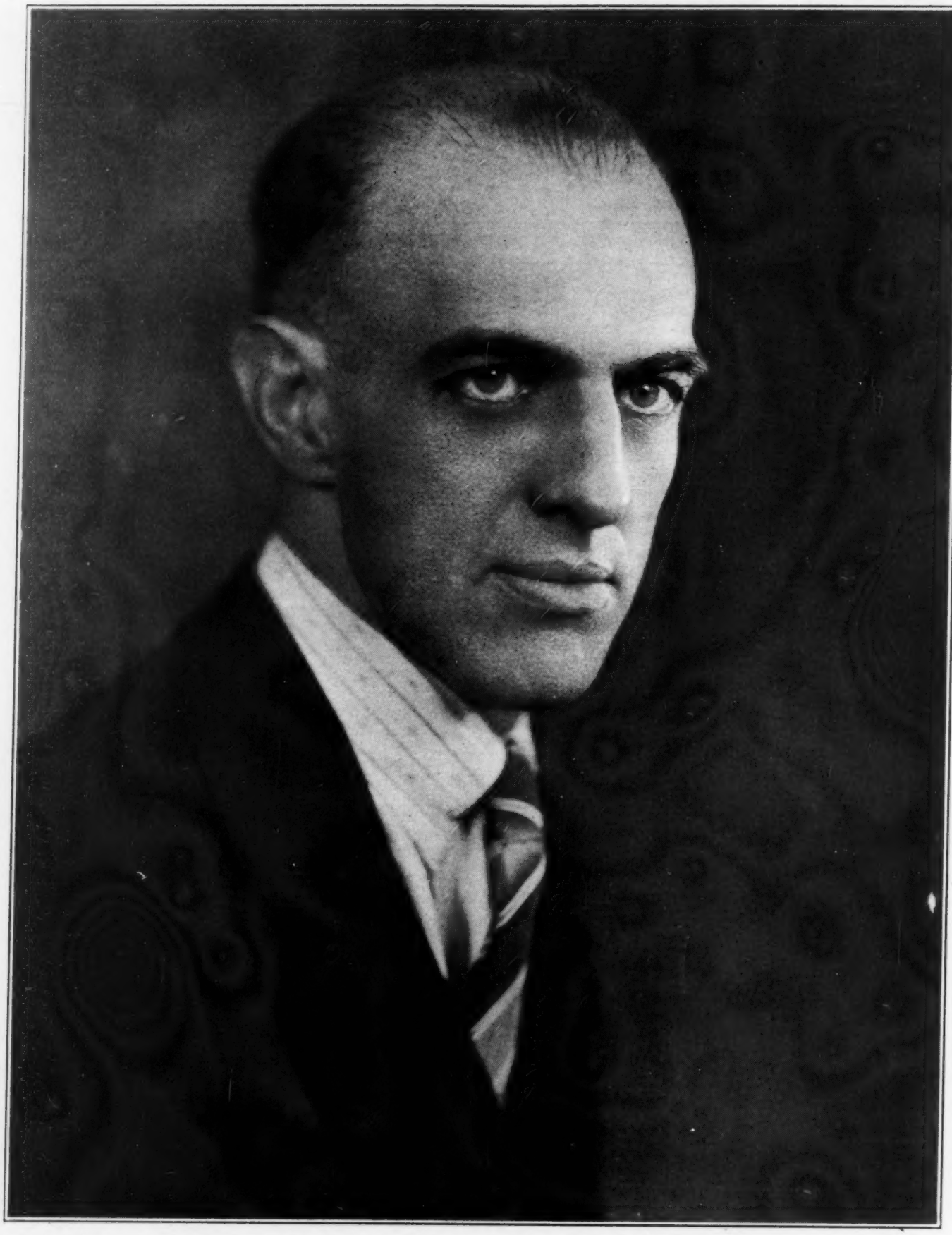
Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.
Subscription Price $5.00 per Year. Single Copy 50c

Tech 53



Mr. F. W. Cramer, Chief Electrical Engineer of the Republic Iron and Steel Company, Youngstown, Ohio, President of the Association of Iron & Steel Electrical Engineers for the year 1929-1930.

EDITORIAL

Work To Be Done

THE FUTURE SUCCESS OF THE IRON AND STEEL INDUSTRY WAS NEVER BETTER ASSURED THAN IT IS TODAY, BUT THERE IS PLENTY OF WORK TO BE DONE. IT IS NOT POSSIBLE TO STAND STILL AND IT IS REASONABLE TO SUPPOSE, THAT THE GENIUS, THE ENERGY, THE SPIRIT, THAT CARRIED US THIS FAR, WILL CERTAINLY ENABLE US TO CARRY ON.

MANY OLD PROBLEMS REMAIN YET TO BE SOLVED. OLD METHODS, SYSTEMS, PROCESSES AND EQUIPMENT STILL CAUSE WASTE, TROUBLE, LOSS AND DESTRUCTION.

NEW PROBLEMS ARE CONSTANTLY ARISING, DUE TO ADVANCES IN THE ARTS AND SCIENCES.

NEW DETERMINATION OF PROPERTIES OF MATERIALS MUST BE MADE TO SATISFY THE DEMANDS FOR QUALITY.

MANY PROBLEMS TODAY IN THE IRON AND STEEL INDUSTRY CONCERN MATERIALS, METHODS, PROCESSES, EQUIPMENT AND PERSONNEL.

A MAJOR PROBLEM FACING THE WHOLE INDUSTRY TODAY IS ELECTRIC HEATING AND WELDING. TEN YEARS AGO IT WAS GIVEN NO CONSIDERATION; TODAY MILLIONS OF DOLLARS ARE BEING APPROPRIATED FOR RESEARCH, PROCESSES AND PRODUCTION EQUIPMENT IN ELECTRIC HEATING AND WELDING.

TEN YEARS IN THE FUTURE WILL SEE THE MODERN ROLLING MILL OF TODAY OBSOLETE AND THE HUMAN ELEMENT BEHIND SCREENS, SERVICING MECHANISMS THAT WILL OBEY THE WAVE OF THE HAND, THE CALL OF THE VOICE.

TRULY, THERE IS PLENTY OF WORK TO BE DONE.

THE ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS REALIZING THEIR RESPONSIBILITIES IN THE PROGRAMS OF THE FUTURE, WILL CONTINUE TO GATHER AND DISSEMINATE THE KNOWLEDGE AND EXPERIENCES OF THE EXECUTIVES AND ENGINEERS IN THE FIELD OF OPERATION, WHICH IN THE PAST HAS BEEN AN ESSENTIAL FACTOR IN THE PROGRESS OF THE INDUSTRY.

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Gas Producers *

By F. E. LEAHY†

As indicative of the status of gas producer development, a description of a gas producer installed and in operation for the past two years in the Seamless Tube Department of The Youngstown Sheet and Tube Company follows:

This producer is one of nine, and is of a more recent design than the remaining eight producers. A discussion of the producer house, which was placed in operation the latter part of August, 1926, follows:

The producer house contains nine producers, and is equipped with coal handling, crushing, and screening machinery. Coal is brought in by cars at yard level, from which the coal is dumped into a 100-ton bin and from here elevated to the coal crushers, the coal from which is discharged into either of two 2-ton buckets. The coal is dumped from the buckets over screens, 1½" mesh, and from the screens is discharged into a 140-ton bunker. The fines that pass through the screens are delivered into a 40-ton bin, and from this bin into cars for delivery to the boiler house as slack. The coal is taken from the coal bin by 5-ton larry cars provided with weighing equipment for distributing the coal to 75-ton coal bins located over each gas producer. One producer from the group of nine was reconstructed approximately two years ago to gasify on an average 5000# of coal per hour. The inside diameter of the lining is 10 feet. The producer was also equipped with two leveler bars, the standard equipment being one leveler bar, and one automatic coal feeding hopper. Ash removal apparatus is provided by means of which the ashes from the producer are removed at intervals of approximately 8 hours. The quantity of ashes removed varies with the rate of firing, and will amount to from 12" to 24" of the producer height. The producer is rotated at the rate of one revolution in six minutes. Each revolution of the coal hopper discharges on an average 88# of coal per revolution. The speed of the coal hopper is manually adjusted to the varying demands placed on the producer. On the outlet of the producer is a 10-foot diameter Cyclonic type dust catcher for removing the dust carried over in the gas.

After the producer had been put into operation, preliminary observations were made on the operation to determine the quantity of coal that could be satisfactorily gasified. Very satisfactory operation was secured at varying gasification rates, averaging from 4000# to 6500# of coal per hour during continuous operation, without any difficulty with the producer with the coal used. A five day test was then conducted, and an average gasification rate of 5988# of coal per hour was obtained, and at the end of the fifth day the fire was reported to be in perfect condition. The steam pressure on the blower varied from 50# to 110# gauge pressure during the run. The ashes were removed on an average of from 5 to 6 hour intervals. This run was followed with another covering a period of 104 hours, at an average rate of 6569# per hour. The steam pressure varied, depending on the rate of gasification, and regulated by an automatic regulator operating from the gas pressure varying from 50# to 90# gauge pressure. The average pounds of steam used per pound of coal gasified was .224#. At the end of this run the fire was also reported to be in perfect condition.

As a guide to the gas made, the following average gas analysis covers a long period of operation, and this analysis is fairly representative of the gas produced.

CO_2	I11	O_2	CO	H_2	CH_4	N_2	BTU's
4.9	0.7	0.0	24.3	12.9	3.5	53.7	168.81

The average B.T.U's per pound of coal as fired —13,500.

SELECTION OF COAL

Where high rates of gasification are desired it is necessary that the coal be suitable and a number of

F. E. LEAHY,

tests on this producer were made, using coal from different sources and of different grades, to determine the effect on the producer operation. Tests were made on coals from five different mines. Of these the coal tested from the first mine gave very good results, with a good average gas analysis. Coals from the other four mines did not prove equal to the coal obtained from the first mine, and it was interesting to follow the results obtained when coal from different mines were used. To show the variation in results obtained from different coals gasified on the same producer, without specifying the mines from which they were obtained, I will give the conclusions from a number of tests made in regular operation with this producer.

*Presented before Twenty-fifth Annual Convention of the A. I. & S. E. E., June, 1929.

†Combustion Engineer, Youngstown Sheet & Tube Co., Youngstown, Ohio.

Test No. 1

During this test the operation was reported as satisfactory, the fire soft, with less cleaning than normal, and less flue dust troubles. Gasification rate with this coal averaged 6,000# per hour. This coal was considered quite satisfactory for use in this producer at the above rate of gasification, although the sulphur in the coal was considered too high for gas to be used in an open hearth furnace. The average gas analysis for the test was as follows:

CO_2	I11	O_2	CO	H_2	CH_4	N_2	Calculated BTU's per cu. ft.
4.9	0.4	0.0	24.6	12.2	3.3	54.6	159.92

Test No. 2

During this test the producers required constant attention, and the fires were cleaned twice as often as any regular practice. Gasification was reported unsatisfactory, and the steam consumption was high. The amount of flue dust made was double the normal amount, with the fire hard to poke and it was difficult to maintain the operation at 5000# of coal per hour. The average gas analysis for this test was as follows:

CO_2	I11	O_2	CO	H_2	CH_4	N_2	Calculated BTU's per cu. ft.
5.5	0.2	0.0	24.5	12.2	3.1	54.5	153.87

Test No. 3

During this test constant attention was required to keep the feeder operating uniformly. The fires were inclined to get gummy in the center and hard on the walls. The operation was reported as unsatisfactory, and it was possible to obtain only 3500# of coal gasified per hour. Flue dust gave trouble continually, and the producer necks got choked. It was necessary to dump the dust catcher hoppers every eight hours to keep the gas pressure down on the producer. This coal was reported as not satisfactory for use on the producer. While the gas was of fair quality, it was impossible to gasify the coal at any higher rate. The average gas analysis for this test was as follows:

CO_2	I11	O_2	CO	H_2	CH_4	N_2	Calculated BTU's per cu. ft.
7.6	0.4	0.0	21.3	13.1	3.4	54.2	153.2

Test No. 4

This test was made on coal from another mine and the operation was reported as giving trouble with fires tending to work hard on the sides of the producers, and trouble with clinkers. Flue dust was excessive with this coal, the same as in test No. 3. The best that could be obtained was 3500 to 4000# of coal per hour gasified. This coal was also reported to be unsatisfactory for use in this gas producer. The average gas analysis for this test was as follows:

CO_2	I11	O_2	CO	H_2	CH_4	N_2	Calculated BTU's per cu. ft.
6.1	0.3	0.0	23.2	12.8	3.2	54.4	154.48

Test No. 5

This test was made on coal from another source than the previous four tests, and the operation was reported as requiring extra attention to the feeders, also hard fires near the walls due to clinker. It was necessary to poke the fires at 2 hour intervals to keep them working free, and approximately 40% more steam was necessary than in normal operation. There was not so much trouble due to flue dust. On this run it was possible to maintain an average of 4500# of coal gasified per hour. The gas made was of fair quality, but the producer operation required too much extra labor to keep the fires in satisfactory working condition. The average gas analysis for this test was as follows:

CO_2	I11	O_2	CO	H_2	CH_4	N_2	Calculated BTU's per cu. ft.
9.4	0.4	0.0	18.6	16.4	3.6	51.6	157.3

From these runs it was proven that for high rates of gasification, the selection of the proper coal was very important if the operation was to be maintained without excessive manual labor. From these series of tests we were able to select a number of mines that we know the coal from which would result in very satisfactory operation.

BLOWER

The blower used on this producer is known as the Noiseless Steam Jet Blower, and is an application of the venturi principle, using multiple steam jets in a venturi mixer. The blower operation has been very satisfactory, and judging from the uniformity of the gas analysis, the blower is capable of maintaining a very uniform blast temperature over a wide range of capacity.

DISTRIBUTION

In order to secure a satisfactory distribution of the fuel, the producer is equipped with two leveler bars. The addition of the second leveler bar has proven to be amply justified for high rates of capacity, as the fuel bed when using the proper grade of coal, has been found to work very uniformly and free of clinkers at high rates of gasification.

METHODS OF CONTROL

Of particular interest in the working of a gas producer are the methods used to control and direct the operation to secure the maximum quality and uniformity in gas produced. It is well known that for certain heating operations, the quality of the gas made has a direct bearing on the amount of fuel consumed in the furnace. There has been quite some advance made in equipping producer plants with instruments suitable to control and direct the operation. It is no longer the practice to use a steam gauge only, but instruments that will record the steam pressure on the blowers, the gas pressure, the blast pressure, and the gas temperature. Through this method of control, variations from a normal practice can be detected, and corrective measures promptly applied before the furnace operation is seriously handicapped. The use of regulators operating from the gas pressure to vary the steam flow to the producer to maintain a constant gas pressure is in common use, particularly where a battery of producers are used to supply a number of different furnaces. With the possible exception of gas producers for Open Hearth furnaces, this means of control has resulted in appreciable savings, and improvement in the service from the gas house. The use of a measuring rod to check fuel bed levels is also common, and where these controls are part of the daily operation, it is quite usual to find a satisfactorily operating plant.

Through the selection of the proper coal for the rate of gasification required by the particular gas producer plant, directed with carefully selected control instruments, gasification rates are now secured in every day operation from double to triple what was formally considered satisfactory operation.

This, in addition to improving operating conditions at the furnaces using the gas, has resulted in a substantial reduction in the cost of coal gasification.

*Time-Current Control for Direct Current Motors**

By D. C. WRIGHT†

Ever since the first introduction of magnetic contactor controllers for direct-current motors in the early nineteen hundreds, there has been a steady improvement in the methods used for automatic acceleration of the motor. Numerous schemes of connections and types of relays have been used. These, in general, have been improvements over preceding types; but all have had their disadvantages; hence, the requirements for improvements has constantly existed as the art progressed.

For many years, current limit acceleration held the field. Without a doubt, this scheme protected the motor, by reducing commutator trouble due to excessive peaks of current when accelerating normal loads and by reducing burn outs due to excessive current in accelerating overloaded machinery. We all know, however, that it did have the one disadvantage of not allowing the motor to be occasionally forced to accelerate an overload when conditions demanded. This disadvantage was not so apparent on older designed motors, which did not have much momentary overload capacity and which could not be forced to accelerate. However, improvements in motor design have accompanied improvements in the electrical art, so that the present mill type motor, or even the general purpose industrial motor, will momentarily stand enormous overloads. Mill machinery has also been improved, either by making the parts heavier or by using alloy steel, so that it in turn will stand larger overloads.

These improvements in motor and machinery design have demanded an improvement in the method of acceleration, hence the arrival, a few years ago, of Time Limit Acceleration. Various schemes and types of relays are used to give a definite time between closure of accelerating contactors, so as to allow the motor to increase its speed and build up its counter-E.M.F. before finally being thrown across the line. This scheme of acceleration overcomes the one serious disadvantage of the Current Limit Scheme, in that, the motor may be forced to accelerate even when overloaded. The system must be protected by an overload relay in the controller and motor circuit to prevent damage to machinery and motor, in case the motor is absolutely stalled. If not so protected, the motor, after the short interval of time afforded by the controller, will be thrown across the line under its stalled condition. This may cause a smashing of machinery, a motor burn out, or the blowing of a circuit breaker down the line somewhere, with the resultant loss of production due to stopping other motors.

Straight Time Limit Acceleration, although it allows forced acceleration when demanded, also has its disadvantages. Even with the present day, well-designed motor, sufficient time must elapse between closure of successive accelerating contactors on normal loads, so as to keep the peak currents to a normal value. With this setting for ordinary conditions, the rate of acceleration will be too rapid for proper protection of the motor under extreme conditions of load. On the other hand, if the rate of acceleration is set for the extreme conditions, the motor will take entirely too much time to accelerate on ordinary or light loads. Production of the mill will be reduced, as full advantage cannot be taken of the characteristics of the series type motors more often used in mill service. A constant rate of acceleration, regardless of load, is hardly applicable in any class of machinery. It requires excessive strength of machinery and excessive power requirements for maximum loads without the advantage of the saving of time when accelerating light loads. We do not accelerate our automobile up hill at the same rate as down hill—then, why accelerate an ore load on a skip hoist at the same rate as a coke load? Why not take full advantage of the series motor and allow it to accelerate fast on light loads and protect it and its load against fast acceleration on heavy loads?

Time-Current Acceleration; that is, acceleration where the time is modified by the current or load on the motor, has been developed so as to overcome all of the disadvantages of straight time acceleration. The rate of acceleration, or in other words, the time between operation of successive acceleration contactors is increased as the load on the motor increases. A lightly loaded motor accelerates rapidly; a heavily loaded motor accelerates slowly, thus effecting a saving in power demand, a saving in wear and tear on the machinery, a saving in time, which increases production, and yet it provides safe forced acceleration when demanded by overloaded conditions.

Before going into the theory of this new scheme of acceleration, I wish first to show you, by means of oscillograph curves, the results obtained on accelerating a motor under various load conditions and various settings of the time adjustment. There is no current adjustment on the control scheme, as this automatically takes care of itself for all time adjustments. Fig. 1 shows the acceleration of a motor under four different load conditions, 25% load, 50% load, 100% load and 150% load. The motor is a standard 20 H.P., 230 V., series-shunt, mill type motor. The controller is a full magnetic plugging controller and has two accelerating contactors controlled by Time-Current Relays, one plugging contactor controlled by a plugging relay. The Time-Current Relays were set at maximum time. A one speed master was used and all accelerating contactors were closed automatically. The resistance allows approximately 75% full load current with

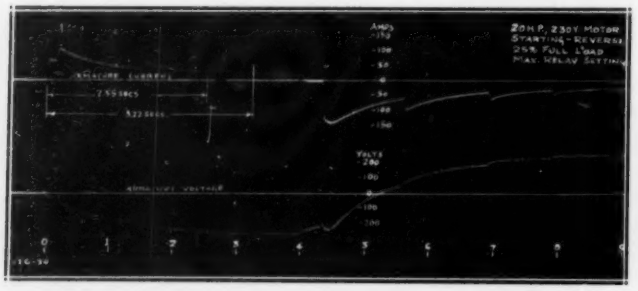
*Presented before Twenty-fifth Annual Convention of A. I. & S. E. E. at Pittsburgh, Pa., June 1929.

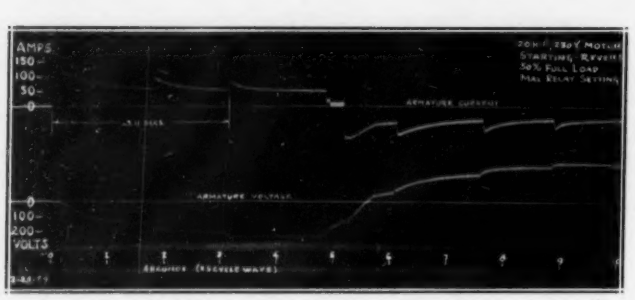
†Chief Engr., Electric Controller & Mfg. Co., Cleveland, O.

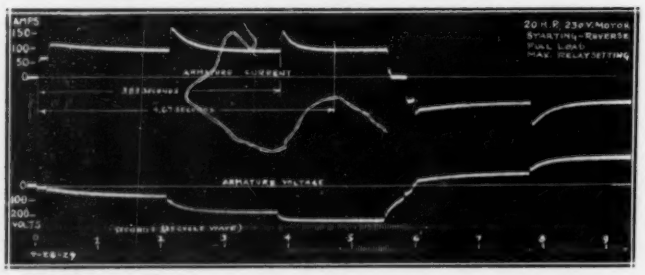
motor at rest. The plugging contactor, which is not restricted from closing when starting from rest, allows 150% full load current. The load consists of a fly wheel on the armature and a friction load which was varied in amount to make up the different loads. Full load is 80 amperes. In starting up from rest, the controller put the motor across the line in 2.55 sec. at 25% load; in 3.11 sec. at 50% load; in 3.83 sec. at 100% load, and in 4.31 sec. at 150% load. In this last test the motor did not start upon closure of the plugging contactor because of the high static friction load. This set of curves clearly show the effect of current, or load, on the time of acceleration. If we take the time of 3.83 sec., that is, the time to accelerate 100% load, then we find that 50% load was accelerated 20% faster and 25% load was accelerated 50% faster. 150% load was accelerated 11% slower.

These curves also show the effect of the plugging relay in action when the motor is plugged at high speed to keep the plugging current down to 50% overload. The plugging relay is adjusted to allow the plugging contactor to close at about the time the motor has come to rest.

Each Time-Current Relay has an adjustment by which the time can easily be reduced regardless of the load. Fig. 2 shows that the time to put the motor across the line can be reduced from 2.55 sec. to 1.18 sec. by this simple adjustment. Or the







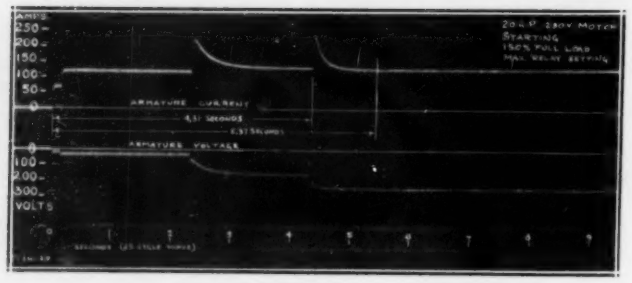
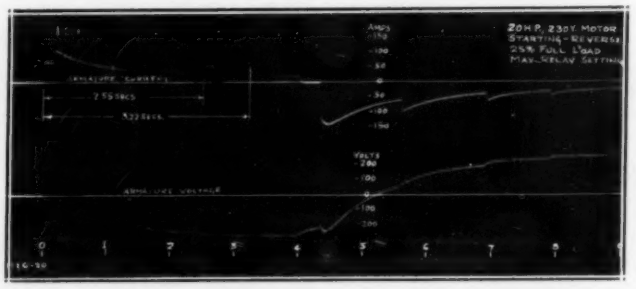


FIG. 1.



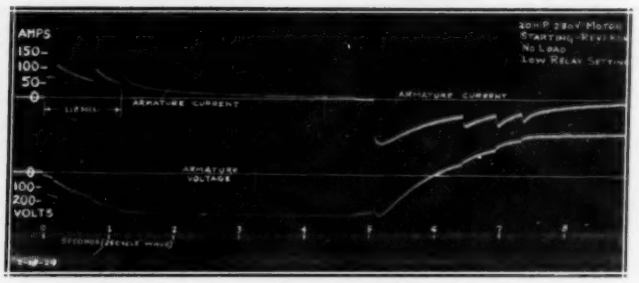
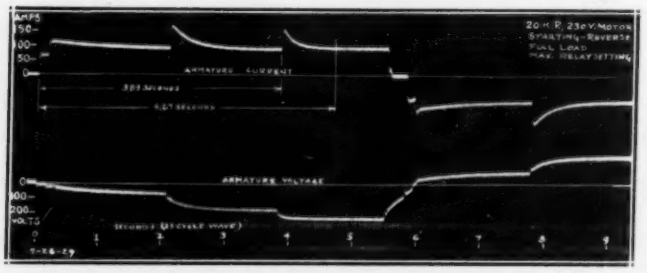


FIG. 2.

speed of acceleration was increased 116%. These curves are from a lightly loaded motor. The plugging relay is not affected by this adjustment and brings the motor to rest before starting in the op-



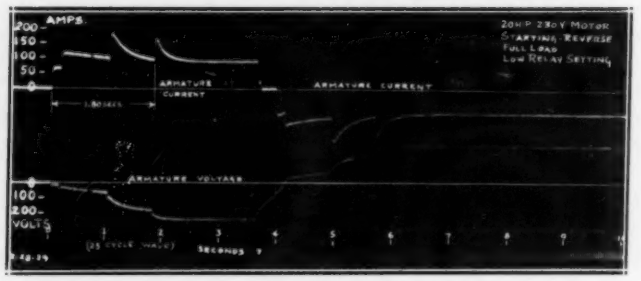


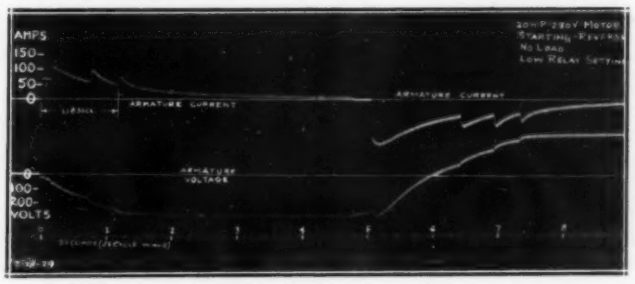
FIG. 3.

posite direction in a time depending on the load, the speed of the motor and on the resistance in the plugging circuit. Fig. 3, on a fully loaded motor,

shows that the acceleration time of the two contactors can be reduced from 3.83 sec. to 1.80 sec. by the same time adjustment or an increase in speed of acceleration of 112%. It will be noted, however, that the current peaks are rather high in the lower current curve. If the load on the motor was constantly of this value it would be advisable to increase the time slightly to allow higher speeds before closure of contactors.

To show that the time adjustment does not interfere with the inherent automatic current adjustment, refer to Fig. 4; which shows the same short time adjustment for no-load and full load. In the first case the time is 1.18 sec. and in the second case 1.80 sec. Light load was accelerated 53% faster than full load.

On stalled or semi-stalled conditions, it is advisable to give the motor every possible chance to get started without undue punishment. The lower curve of Fig. 1 showed that it was possible to accelerate a 50% overload without blowing the circuit breaker; although, of course, the breaker had



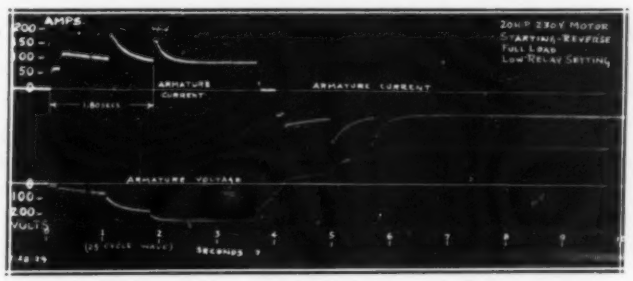


FIG. 4.

to be set above the full load protecting value. Had the motor been stalled, the curve as shown in Fig. 5 would have resulted. The plugging contactor closes almost immediately, giving approximately 150% full load current. The motor did not start even though the current hung on for 2.03 sec., at which time the first accelerating contactor closed, giving 250% full load current. The motor would not start even with this high current and after 2.75 sec. the second accelerating contactor closed, immediately blowing the circuit breaker on the controller, thus relieving the motor and controller from any serious damage. A second attempt at starting could have been made by bringing the master controller to the off position to reset the circuit breaker and again starting. However, no controller could have accelerated this motor under the extreme overload conditions, and the overload has to be reduced before the motor could be put in service. It is interesting to note that, at 120 amp. stalled current, the relay took 2.03 sec. to operate and at 200 amp. it took 2.75 sec., an increase in time of 35% due to the increased current.

Inching, which is frequently necessary in mill operation, presents an interesting problem. With a straight time controller, it takes just as long to get the motor back on the line, after the circuit has been interrupted by inching, as it did to start it from rest. Fig. 6 shows that with a Time-Current Controller at maximum time setting and at 25% full load, the motor was put back on the line again, after a brief interruption by inching, in 1.32 sec. as against 2.55 sec. to accelerate from rest.

There are some types of loads where time or Time-Current acceleration may not give proper results. For instance, a heavy fly wheel load, which takes a long time to accelerate to full load speed, may cause excessive current peaks at the end of acceleration unless sufficient time elapses between closure of contactors, or unless a sufficient number of contactors are used to allow the motor to get

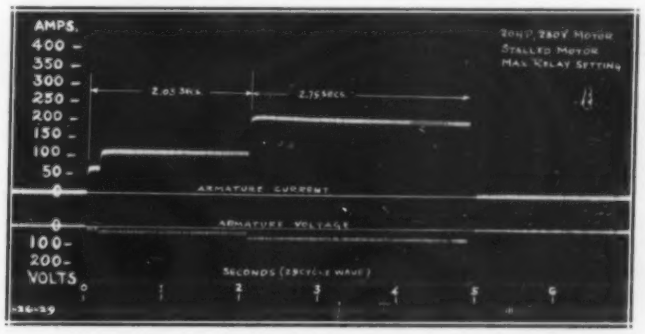


FIG. 5.

up to a high speed before being put across the line. Time-Current acceleration with its automatic increase in time, due to load, gives the maximum time possible; but with this type of load, the conditions should be studied to see that a sufficient number of contactors are used. The results, obtained from the addition of an extra contactor, are shown in Fig. 7. Here, three accelerating contactors controlled by Time-Current Relays were used instead of two. The total resistance was of the same amount as in Fig. 1 but the resistance taps were re-proportioned

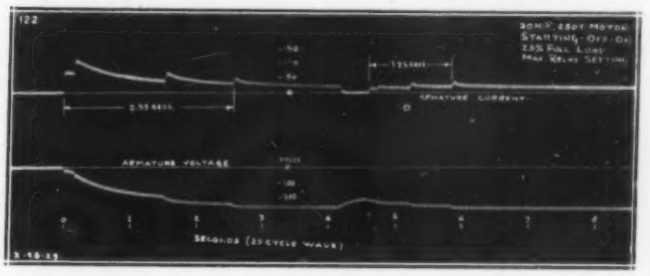
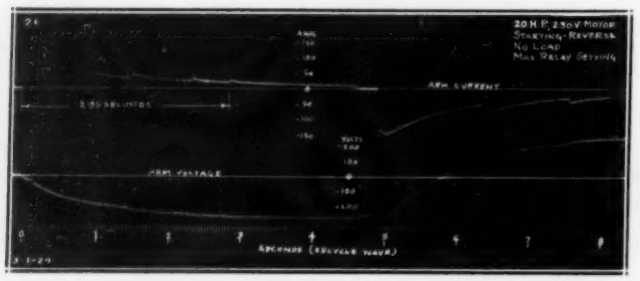


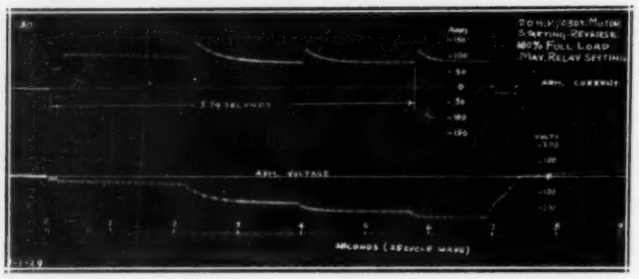
FIG. 6.

for the additional step. The loads were the same as before. The times to get the motor across the line from rest are 2.85 sec., 4.34 sec., 5.74 sec. and 6.22 sec., as compared with 2.55 sec., 3.11 sec., 3.83 sec. and 4.31 sec. It will be noted that the increase in time is not in direct ratio to number of contactors used. This is due to the lower current peaks where more contactors are used. The maximum peak, at

50% overload where two accelerating contactors were used was 230 amps. as against 180 amps. peak where three contactors were used.

Stalled conditions with three contactors are shown in Fig. 8. In this case the first accelerating contactor did not cut out so much resistance, the stalled current being 170 amps. instead of 200 amps. as in Fig. 5. The time for closure of the second accelerating contactor was therefore less. The





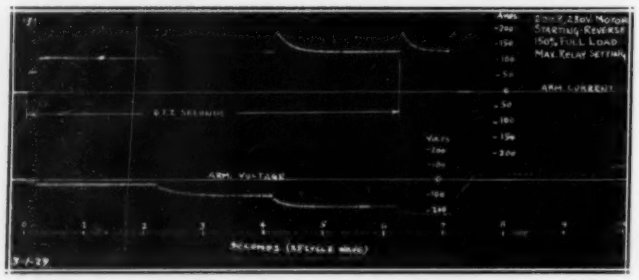


FIG. 7.

closure of the second accelerating contactor gave 270 amps. and blew the circuit breaker before the motor was put on the line and before damage was done to either motor or controller.

As stated before, all these curves were made on a mill type motor. Had a shunt wound motor been used, the time of acceleration in all cases of load would have been slightly longer due to slower inherent acceleration of the shunt motor and the slightly higher current peaks after closure of the first acceleration contactor.

THE TIME-CURRENT RELAY

The relay used to give the above Time-Current results is a separate piece of apparatus not mechanically attached to the contactor, nor a part of it. For this reason standard contactors can be used for the accelerating, plugging, and reversing elements of the controller. The relay is of the inductive type. Induced current gives the power to operate the relay and to provide the retardation to give the time. The construction of the relay is shown in Fig. 9. We have here, a coil *A* of heavy wire or strap connected in the motor circuit; an iron enclosing case *B* and an adjustable steel core *C;* a stationary steel tube *D;* and a movable aluminum tube *E,* in the air gap *F,* between the case and the plug, and carrying the contact bridge *G,* which rests on the stationary contacts *H* at its lowest position. The contact members are of pure silver, and are enclosed in a hinged aluminum cover.

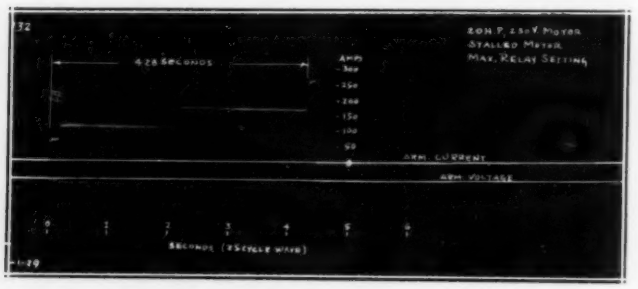


FIG. 8.

Operation:

When no current is flowing through coil *A* there will be no magnetic flux in air gap *F* and therefore no action takes place. However, when current is

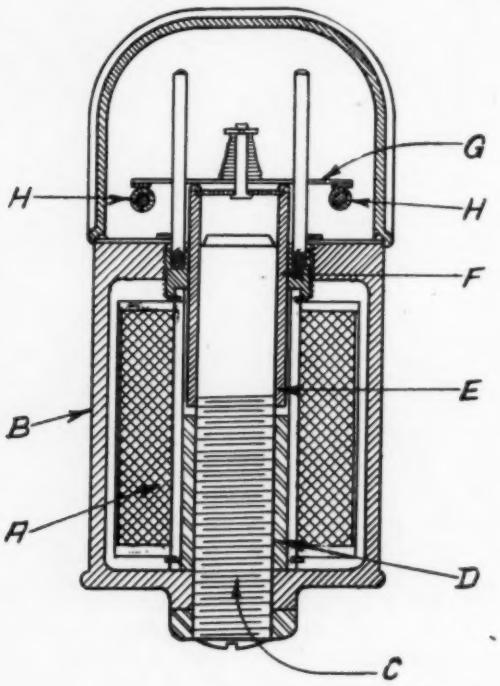


FIG. 9.

passed through coil *A*, magnetic flux in air gap *F* builds up from zero to its maximum. All of this flux passes through the aluminum tube *E* and all of the lower end of the tube from the air gap down is enclosed by the magnetic field. As long as the flux is changing in value, this part of the tube acts as a secondary of a transformer, and current is generated or induced in the tube which becomes a short circuited turn enclosing a quickly changing magnetic field. The induced current in the tube acts the same as current in any conductor. A strong magnetic field is caused to flow around the conductor; in this case, around the tube from top to bottom. This magnetic field is in opposition to the field set up by the coil *A* in the core *C*. Therefore, the tube *E* will be repelled upwards, as long as there is any change in the flux in the core *C;* or in other words, as long as induced current flows in the tube.

The current in coil *A*, since it is a series coil, builds up rapidly; therefore the flux in core *C* and the induced current in tube *E*, also build up rapidly, causing the repelling force to act instantly almost like a blow. The tube jumps upward with a considerable force and would travel a foot or more if it were not retarded by another electrical phenomena. As the tube starts moving, there is already a magnetic field set up in air gap *F;* and the tube, therefore, starts cutting this field as it moves upward. As it cuts through this field, eddy currents are set up in the tube. Generation of these eddy currents causes a retarding action, just the same as a wattmeter vane is retarded when being forced through a magnetic field. This retarding action, plus the force of gravity, overcomes the repelling impulse before the lower part of the tube has entirely left the air gap *F*. The tube, therefore, stops; and then starts to fall under the force of gravity. If there was no flux in air gap *F*, the tube would fall at a speed depending on gravity only. However, motor current is still flowing through coil *A* and there is a considerable magnetic field in air gap *F*. Therefore, as the tube falls, it is retarded by the eddy current effect, the same as it was retarded in the upward direction. This slow movement in the down direction gives us our time, which may be as long as 2.75 sec. on a stalled motor where the air gap *F* is saturated with a magnetic field.

It was explained that the sudden application of current through coil *A*, suddenly builds up a flux in core *C*, and that this change in flux, induced a current in Tube *E*, causing a reacting flux around tube *E*, making it jump upward. It can readily be seen that a lower current in coil *A*, or a fewer ampere turns, would cause the flux in core *C* to build up slower and to a smaller value. The induced current would be less; the propelling force less; and the tube would not jump so high. However, the height of movement is not in direct proportion to the current, as the induced eddy currents in tube *E* are greater at high currents in coil *A* and the retarding force is greater.

With lower currents in coil *A;* the flux density in the air gap *F* is less; therefore, the eddy current effect when the tube is falling, is less, and the tube will fall more rapidly. Thus, with lower current the tube jumps to a less distance and falls more rapidly. The time of operation depends upon the current; hence, Time-Current Control.

When connected in a control system the current in coil A is the current taken by the motor and is limited by the resistance in the circuit. If the motor starts on this current, the counter-E.M.F. starts building up and the current starts reducing before the tube has dropped. This lessening current causes the tube to fall faster. If the motor does not start or starts very slowly, the current stays up at its high value and the tube falls more slowly, hence, the increased time on heavily loaded or stalled motors.

Another interesting phenomena in this relay is the downward pull on the tube when the current in coil A is broken as the tube is falling. This sudden pull is almost as strong as the upward thrust when the current is established and is caused by the sudden collapse of the flux from a high value to zero. This action does not take place frequently but occurs on one relay every time the master is brought to the off position during the acceleration of the motor. The strong upward thrusts and downward pulls tend to throw off any dust which might accumulate on the aluminum tube or in the air gap.

The upward thrust is proportional to the rate of change of flux in the magnetic circuit. With a series coil, the rate of change is very rapid when the current is first established. The initial thrust is enormous for so small a piece of apparatus. The rapidity of operation of the *SI* relay is clearly shown in Fig. 10. The diagram shows that the series coil

FIG. 10.

of the relay and the shunt coil of the contactor were energized simultaneously. The relay had an

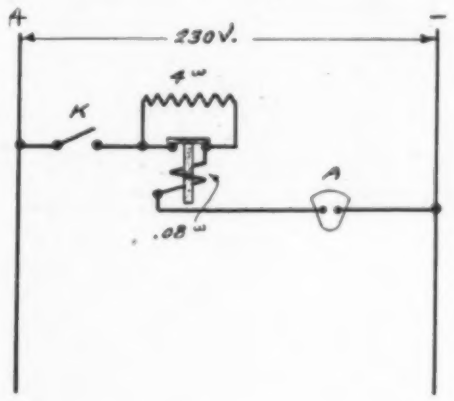


FIG. 11

extra set of stationary contacts added to make circuit after .6" of travel. The top oscillograph curve indicates current in the series coil. The middle

curve shows current in the shunt coil of the contactor and the lower curve is the timing wave curve, the film being speeded up so as to accurately measure the extremely short intervals of time. When the relay was energized the tube immediately jumped, breaking circuit with the lower contacts and was brought to rest by making circuit with the upper contacts. The tube then slowly dropped away from the upper contacts. The middle curve shows that it took two one-thousandths of a second; that is .002 seconds, for the relay to break the circuit to the shunt contactor, after the two coils were energized. It then took .0152 seconds for the relay tube to travel .6" before again making circuit to the contactor coil. A small size contactor was used in this test. The closing time of this particular contactor is approximately .18 seconds. It is thus seen that the relay operates almost 100 times as quickly as the contactor. On larger contactors the relative difference in speed of operation is even greater because of the slower operation of the larger contactor.

Another interesting test was made to show the rapidity of operation of the relay. A relay was connected in circuit as shown in Fig. 11. Upon closure of switch *K*, the coil of the relay was thrown across the line in series with the control circuit contacts of the relay and in series with a 100 amp. ammeter. A four ohm resistor was connected across the control contacts so as to maintain a circuit through the relay coil after it had operated. The resistance of the coil was .08 ohms. The calculated current through the contacts was 2700 amperes before the relay jumped and 57 amperes after the contacts broke. The high circuit was broken so quickly that there was scarcely any flash at the contacts

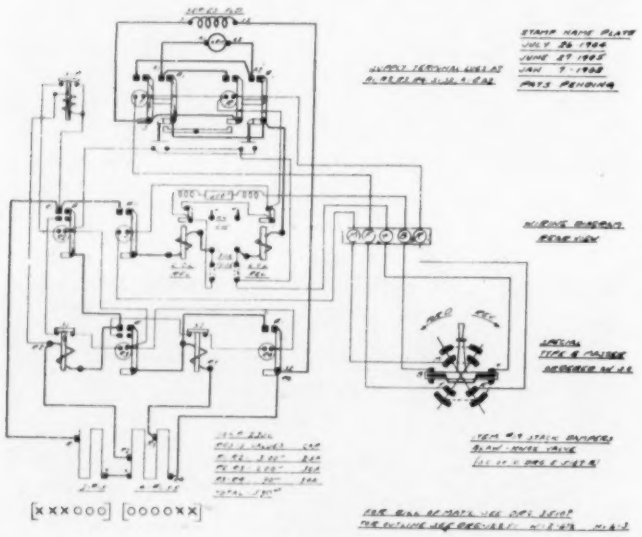


FIG. 12.

and the ammeter needle showed hardly any movement. The silver contacts were only slightly burned and were still in operating condition.

A further interesting phenomena in the action of this relay, is the fact that the aluminum tube does not rub on the central core or the magnetic enclosing case as it raises and falls. This is due to the concentric construction which allows all magnetic forces to balance each other. The tube simply floats in a magnetic field as it raises and lowers. This phenomena eliminates all wear, which otherwise might occur from frequent operation.

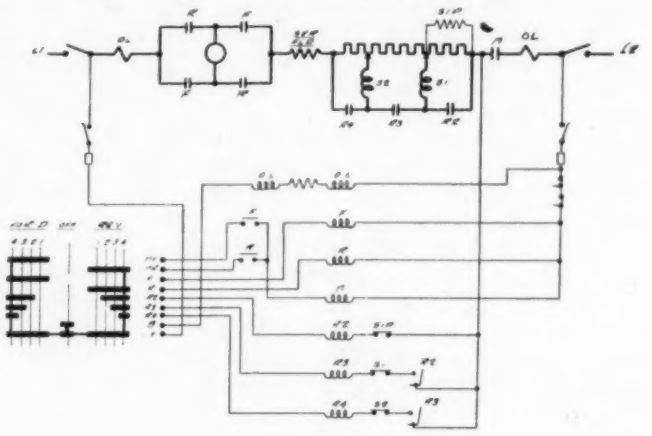


FIG. 13.

It is interesting to note that if there is already a current established in the operating coil of the relay and this current is increased, there will be scarcely any jump of the relay tube. This is due to the fact that the induced current in the tube is in proportion to the rate of change in flux. The rate of change is very much more rapid from zero to a fixed value, than from some fixed value to another higher value.

ADJUSTMENT

The core *C* is adjustable up and down in the frame *D*. When the core is at its top limit, the reluctance in air gap *F* is a minimum, and, for a given amount of current, the flux in tube *C* and air gap *F* is a maximum; therefore, the tube will jump to the highest distance and will drop at the slowest speed. If the core *C* is lowered, the reluctance in the magnetic circuit is increased and the flux in *C* and *F* will not be so great. The tube will jump a lesser distance and will fall faster. Therefore, to speed up acceleration of the motor, the core *C* is lowered. It can be lowered about 1½ inches so that practically no time element is had from the relay.

FIG. 14.

CONTROLLER CONNECTIONS

A full diagram of a single speed plugging controller is shown in Fig. 12. This controller is similar to the one on which the oscillograph curves were taken and shows double-pole reversing contactors; a circuit breaker contactor, all controlled from the master switch; a plugging contactor, controlled by the plugging relay; and two accelerating contactors, controlled by Time-Current Relays. The shunt coils of the contactors are designed for continuous operation on normal voltage without resistors except on 550 volts, in which case, 230 volt

coils with permanent resistors are used. The resistor unit shown is for the overload reset magnets.

The Time-Current Relays are connected so as to be shorted out of the circuit by the contactors

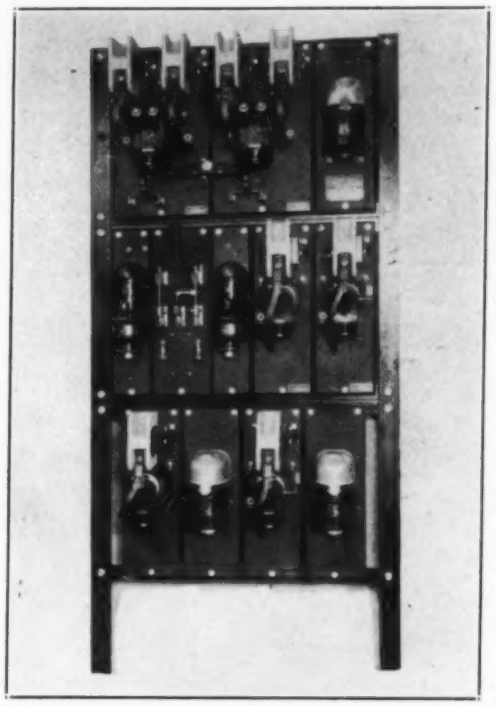


FIG. 15.

controlled by them; therefore, for automatic acceleration, none of the relay coils can be in circuit for more than two seconds except under stalled conditions, when the load would be relieved by the overload relays. The service on the relays is therefore less than on the starting resistance. Due to simplicity of circuits any Time-Current diagram is easy to follow. There are no complicated shunt circuits of unknown action to decipher. All that one has to remember is, that the Time-Current Relay opens the circuit to its contactor before that contactor has time to close and then, after an interval of time, again makes circuit to its contactor to allow it to close. The circuit remains completed until the master circuit is opened.

Fig. 13 shows the simplified shunt connections for a 4-speed reversing controller such as would be used for the trolley or bridge motions on a crane, or other similar motions, where it is desired to control the speed of acceleration, manually as well as automatically. With such a controller the motor can be held on any resistance step as long as desired, or the master can be thrown to the last point and the acceleration will be taken care of by the Time-Current Relays.

DUPLEX DRIVES

On duplex drives, it has always been The Electric Controller and Manufacturing Company's policy to supply duplex controllers; that is, controllers made up of double-pole reversing and accelerating contactors. This arrangement entirely divorces the motor connections and prevents all chances for circulating currents, which are very likely to occur unless motors are carefully balanced where a single set of reversers or a single acceleration train is used; or where two separate controllers are used and the acceleration of each is not at the same rate. With double-pole accelerating contactors, a single set of accelerating relays connected in one motor circuit is used. This arrangement forces both motors to accelerate simultaneously, the rate being governed by the power taken by one motor.

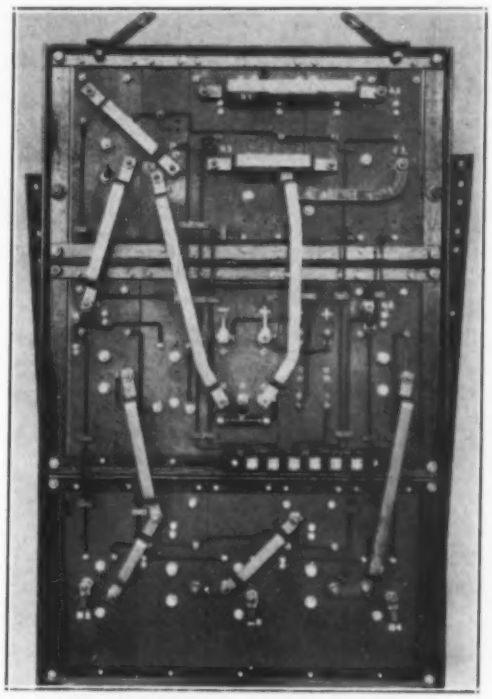


FIG. 16.

Our policy on duplex controllers is still the same. A single set of Time-Current Relays will be furnished with the double-pole accelerating train. One

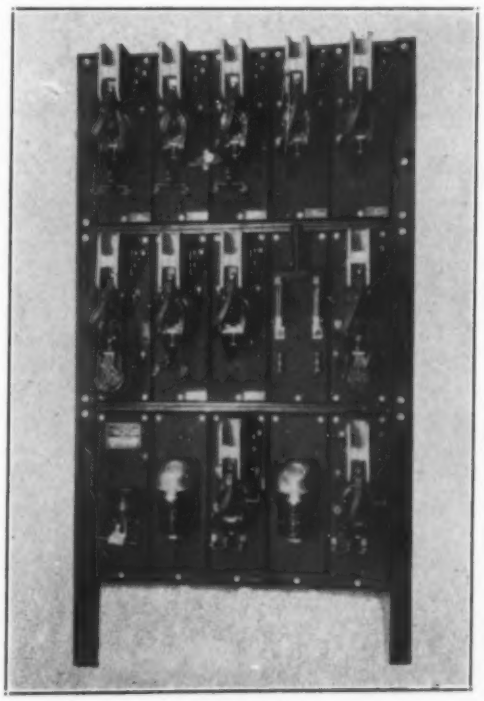


FIG. 17.

of the principal advantages of duplex drives, aside from mechanical advantages, is the ability to cut out one motor and operate on the other in case one motor becomes disabled. Time-Current Acceleration gives great advantages over either current limit or definite time limit acceleration, under such conditions. When one motor is cut out, the other is generally overloaded, and with current limit acceleration, the relays either have to be readjusted to allow the contactors to close, or shorted out, or are adjusted for fast operation on normal service when the two motors are used. With straight time acceleration, if the time relays are set properly for two motors, the time will not be sufficient with only one motor in circuit and the overload relays are likely to open the circuit. If the time is set properly for a single motor, then the rate of acceleration is entirely too slow for two motors in the

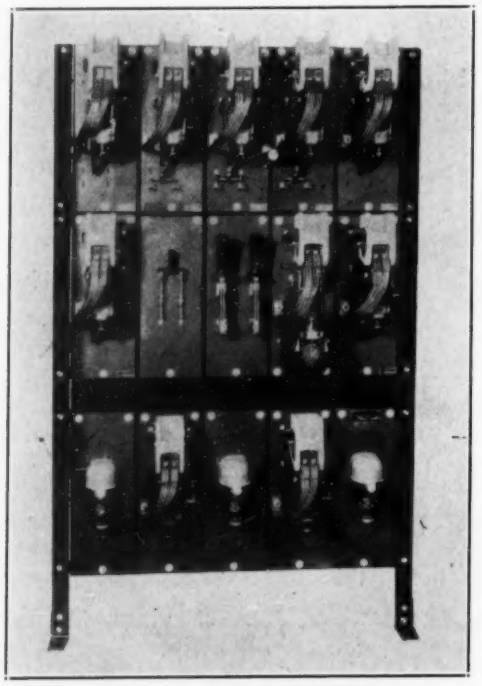


FIG. 18.

circuit. With Time-Current, a setting which is proper for two motors will adjust itself to the load when one motor is cut out, so that all that is necessary is to manipulate the cut-out knife switches when one motor is disabled.

PLUGGING RELAY

A single plugging relay of the magnetic type is used to control the plugging contactor on reversing controllers. The relay is so constructed that its pick-up value is only about 10% higher than its drop-out value. The coil is a shunt coil used without resistor units on 115 and 230 volt circuits and is connected permanently across the first step of starting resistance. When starting from rest, the voltage drop across the first step is below the pick-up value of the relay; the contacts, therefore, remain closed and the plugging contactor has a circuit for closure. When the motor is plugged, the total voltage drop across all the resistance is equal to the line voltage, plus the counter-E.M.F. of the motor. The drop across the first step in plugging is therefore increased and if the counter-E.M.F. is 15% of the line voltage when the motor is plugged, the relay will lift its plunger and prevent the plugging

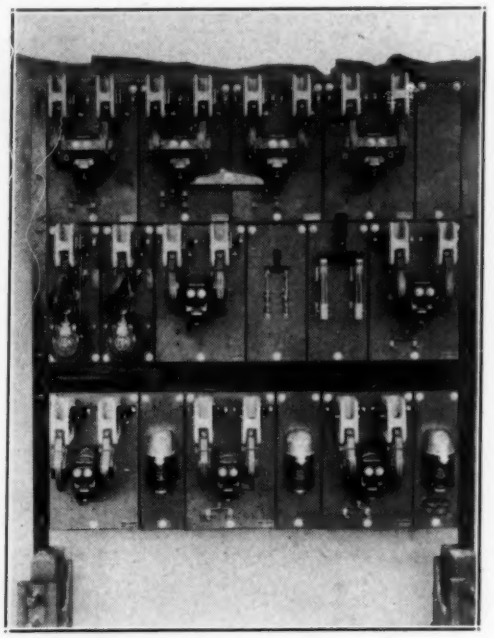


FIG. 19.

contactor from closing until the counter-E.M.F. has reduced sufficiently for the drop across the first step of resistance to reach the drop-out value of the relay. This occurs when the motor has just about reached zero speed, so that the motor is accelerated

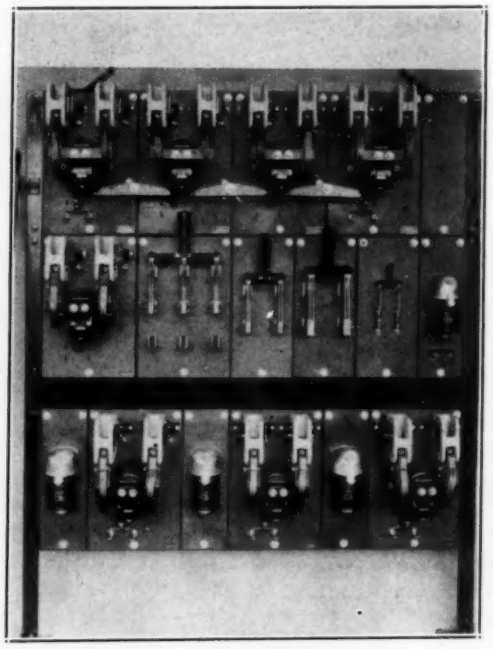


FIG. 20.

in the opposite direction the same as when starting from rest. The relay is adjustable as regards pick-up and drop-out values. Therefore, by proper and simple adjustment, the plugging can be forced; that is, the plugging contactor can be made to close before the motor comes to rest. The plugging relay has a continuous capacity coil and since it is connected

in circuit only as long as the motor is being brought from full speed to rest, the heating on the coil is very slight, even on frequent plugging drives. The change in operation of the relay, due to change in temperature of the coil, is only slight.

The coil of the plugging relay and the coil of the plugging contactor are energized almost simultaneously, but the relay acts much faster than the contactor and therefore breaks contact to the contactor before it has had a chance to close. Fig. 14 shows the action of these two elements when a lightly loaded motor is plugged at full speed. The top oscillograph curve is the operating current through the coil of the contactor. The middle curve shows voltage across the relay coil. When the plugging circuit was established, the voltage on the plugging relay built up to about 200 V. This voltage gradually reduced as the motor slowed down for 2.548 sec. until the voltage on the relay was about 110 V. when the relay plunger dropped allowing the plugging contactor to close. Before the relay opened its contacts, current was established through the contactor coil for .033 sec. but in that short time the current could not build up to the operating value of the contactor which actually required .163 sec. to close when the relay dropped.

Assembled controllers are shown in the following figures:

Fig. 15 is a 20 H.P., 230 V. plugging controller, similar to the one on which the test curves were taken.

Fig. 16 is the rear view of a magnetic controller, showing the simplicity of bus-bar and control wiring.

Fig. 17 is a 65 H.P., 230 V. Hi-speed dynamic braking hoist controller.

Fig. 18 is a 100 H.P., 230 V. standard dynamic braking hoist conotroller.

Fig. 19 is a 180 H.P., 230 V. standard Duplex dynamic braking hoist controller without cut-out knife switches.

Fig. 20 is a 180 H.P., 230 V. Reversing duplex controller for a bridge drive on a ladle crane and has cut-out knife switches so that either motor can be cut out of circuit.

Steel Plant Lighting

By M. H. MORGAN, Jr.*

The glow of the hot metal itself undoubtedly furnished the only working light for the making of iron and steel in the time of Tubal Cain and for centuries threafter. Processes and products were crude, artificial light was expensive and safety was unheard of. Today we have come a long way from that state and are yet changing from month to month. Specifications for finished material are becoming more and more exacting, requiring closer control of processes and more frequent and thorough inspection, while safety of workmen is a matter of primary importance.

It is my purpose to show you that under the conditions which now obtain the following is true of lighting in Steel Plants:

1. That good light is cheap—because of great advances in the art of making electric lamps and shades and because of the very low cost of electric power to steel plants.
2. That good light is of the essence of safety—because we must be able to see well to be safe.
3. That good light is a powerful aid to production—because men can and will do more and better work when they can see well.

I shall also set down certain qualities and characteristics which a good Steel Mill Lighting System must have and say a little about the care necessary to maintain it properly, but it is my chief purpose to show that the lighting system has an important bearing upon the welfare of the workmen and the quality and cost of the product and that it deserves consideration and justifies expenditure commensurate with its importance.

*Electrical Engineer, Carnegie Steel Company, Edgar Thompson Plant, Braddock, Pa.

Good Light Is Cheap

Good light is cheaper in most cases than the very floor it illuminates; it is about the same in both first cost and operation as toilet and janitor facilities and equally as essential to the health and comfort of the workmen and the cleanliness and sanitation of the plant as these latter are.

A good interior lighting system may be installed in steel works building for from 5c. to 10c. per square foot, depending upon the class of work done there and the amount of light which that work requires. This system may then be maintained and operated for from 2c. to 4c. per square foot per year, assuming that it is used 12 out of the 24 hours, which is an average figure. Exterior lighting is harder to estimate because so much of the cost depends upon whether or not existing buildings and poles may be used to support fixtures and wiring. Where this is available, the cost of installation is about half that already given because the intensity used is much less and the operating cost somewhat less than half because it is practically never necessary to use outdoor lights during daylight, whereas a dark cloudy day frequently requires artificial lighting of interiors.

Good Lighting and Safety

Good light is of the essence of safety. Sight is by far the most useful, the keenest, and the most important of the senses which inform us of obstacles, moving objects or other impending dangers, and safety most often depends upon quickness of perception of impending danger. The eye, like any camera, requires a small but definite length of time

to receive an impression and transmit it to the brain and as you might expect, laboratory tests show that within reasonable limits this time decreases sharply as the quantity and quality of illumination increases. Thus with the help of good light, there is yet time to get the endangered hand or foot out of the way or dodge a moving object, while under poor light there may not be.

Proof of these statements is contained in a report compiled from the claim records of one of the largest accident insurance companies in this country—The Travellers. These records are the result of the investigation of every accident claim made against this company, and from them a report of causes concerned with lighting is made every few years to the Illuminating Engineering Society. In 1910 the report showed that 23% of industrial accidents were due to inadequate or improper lighting; in 1918 the figure was 18%; and in 1928 it was still 15% in spite of the vast improvement effected in lighting systems during that time.

When you consider the amount of energy and ingenuity expended by both the management and the men to reduce the present total of accidents further, and the fact that such a large proportion are due to "man failure" or carelessness, over which we have little control; the possibility of cutting off a clear 15% with good lighting is most attractive, particularly since greater safety is only one of many ends which good lighting serves.

Statistics collected by a National Safety Committee from employment records state that two-thirds of the men employed in industrial plants have less than normal vision. Some of them have partially or entirely corrected this deficiency with glasses, but a large number have not and are at a great disadvantage even under a lighting system which may be considered "fair" for persons of normal vision. Were the lighting increased to equal the present standards the safety and productiveness of these men should be almost the equal of persons of normal vision.

Light Affects Welfare and Plant Sanitation

Good light is an attractive feature of any workshop. It is pleasing to the men because their eyes are relieved of all strain, and their dispositions of the nervous irritability which so often accompanies it. Good light produces a certain stimulation of itself and is recognized by the men as an added facility and comfort. Checks made in connection with production test before and after the bettering of a lighting system offer convincing proof of this for they have almost invariably shown a decrease in labor turnover.

Good light practically assures cleanliness. The cleanup campaigns in which we have all had to help show that a dark corner is nearly always a dirty one—it furnishes such a good place to throw things—but you know what will happen when good lighting reveals this disorder to the superintendent's eye—it will be cleaned up immediately and stay clean thereafter.

An Aid to Production

Good light is a most potent aid to production. No one can work in the dark—anyone can do some work with a little light and more work with good light. This is self-evident, but it is just as true that a distinct gain in production is the usual result of increasing the illumination in plants of almost every kind from "fair" to that of the present standards. A reduction in the amount of "seconds" produced and less spoiled material due to the workman's greater sureness of eye and lessened tendency to make mistakes is also a usual secondary result. This conclusion is the result of tests made during the past five years upon shops and even entire plants before, and again after bringing the lighting up to present standards.

These tests were conducted in some cases by the management of the plant affected, and in others by the National Electric Light Association or the lamp manufacturers and reported in the proceedings of the various national engineering societies and the technical press. It is likely, of course, that errors exist in individual reports, but the number and variety of tests, the fact that they come from so many different sources, and their substantial agreement would, I believe, convince anyone who examined them that the tendency toward increased production and increased accuracy of work with bettered lighting is a very real and a very forceful one. I quote below from several such reports:

Character of Work	Light Intensity Old	New	Increase in Production
Making babbit bearings-------	4.6	12.7	15%
Heavy machine work --------	3.	11.7	10%
Mfg. piston rings ----------	1.2	18.	25%
Inspecting roller bearings----	5.	20.	12.5%

None are on record from steel plants proper but the plants tested do almost all of the various kinds of work carried on in our service departments—Machine Shops, Bearing Shops, Pattern Shops, Drafting Rooms, Inspection Dept.—and these constitute a large part of a complete steel plant. Likewise it is only reasonable to expect that the operation of Iron and Steel making itself would respond to some extent to the influence which has made itself felt in so many other industries—that of good light.

STANDARDS OF GOOD LIGHTING PRACTICE

Tests and studies conducted from time to time by the National Electric Light Association, the Illuminating Engineers Society, and the lamp manufacturers are embodied in tables which show the intensity of light recommended for almost every manufacturing process as well as for offices and stores of various kinds and other purposes for which light is used. These tables are generally considered the standards for new installations and they are revised from time to time as practice changes. During the past ten years these revisions have all been upward until the intensities recommended today are practically double those of 1918-1920. It follows then that installations made earlier than the past year or two are not usually up to the present standard, and that operations carried on under them do not enjoy the full benefits which we have outlined for good lighting.

Units of Measurement

The unit of illumination intensity used in this country is the food-candle, and that for the amount of light produced by one lamp is the familiar term —candlepower—formerly used as a rating for car-

bon filament electric lamps. The tables I have just referred to are made up in foot candles and while other terms are used to define the quantity and quality of light, we require for this discussion only the two—**Candlepower**—which measures the total light output of a lamp, and **Foot-candle**—which defines the intensity of light delivered at a given point. The **foot-candle** is defined as the intensity of light produced on a flat surface one foot away from a one **candlepower** light when that surface is perpendicular to the light rays from the lamp.

It will give you some conception of these quantities to say that direct sunlight out of doors is approximately 10,000 ft. candles; a shady spot outdoors has an intensity of 100 to 1,000 ft. candles and that at a good north window indoors may be 100 to 200 ft. candles.

The light in this room now averages about ... ft. candles.

The recommended values for industrial interiors range from 5 to 20 ft. candles, far below the natural illumination of the sun, and yet because you have become accustomed to the old standards of artificial lighting, most of you would at first consider lighting which meets these new standards as too good for the purpose. If a lighting system has glare due to faulty installation such as the improper location of lamps or use of the wrong shades the observer is very likely to attribute the ensuing discomfort to "too much light" whereas there may or may not be enough after the defects of location and arrangement are corrected. Therefore when judging the adequacy of a lighting system allowance must be made for the influence of these circumstances.

A small portable instrument known as a foot candle meter is available and is usually used to measure the intensity of illumination at any point. It is about 10x8x2". It is cheap, costs less than $25, fairly rugged and so simple to operate that it may be used by anyone with a few minutes' instruction. It is quite simple to judge the adequacy or deterioration of a lighting system by the measurement of intensity which this meter affords and possible errors of estimation are thus eliminated.

What Constitutes a Good Lighting System

A good steel mill lighting system will have certain recognizable qualities which we may describe without going into too much detail as to how they are attained. Chief among these are:

1. Adequate intensity of light.
2. Freedom from glare—uniformity.
3. Provision for cleaning.
4. Provision for turning lamps off or on singly or in small groups.

The proper intensity will of course depend upon the kind of work done under it and will vary from 1 to 2 ft. candles in yards and storage areas to 20 to 40 ft. candles for inspection of finely finished products as indicated in the table of standards. It is possible to calculate very closely what intensity a new installation will give before it is put in and this is usually done, taking into consideration all the conditions of size and shape of buildings, location of fixtures, and size and type of lamps and reflectors.

The avoidance of glare requires that when lamps of large size are used, the mounting height shall be large or the lamps shall be hidden from direct view by semi-translucent globes or shades and that no lamps of the sizes usually employed be used without shades. In general a large number of small units will reduce the likelihood of glare and improve the uniformity over that obtained with a lesser number of larger units.

Special lighting units are made for steel mill service, some of which totally enclose the lamp and reflecting surface, and others have a very smooth reflecting surface on which grime does not collect readily, but all require some cleaning; otherwise the intensity obtained will soon be far below that for which the system was designed. Thus tests conducted by the Westinghouse Lamp Company show that four weeks of steel mill service reduces the efficiency of a lighting unit by about 15% and by greater amounts if the period without cleaning is longer. A good installation will therefore usually have some means to lower the entire unit to the floor for cleaning or where this is not feasible locate units so that they may be reached from a crane or ladder. The former method is preferable, because one man can clean more units so mounted and because the work is more thoroughly and safely done on the ground.

It is desirable in the interests of economy to split up the total amount of lights used into small groups each controlled by a separate switch so that only the ones needed may be turned on. Thus in a large building having windows on one or both sides, lights will be required in the center or in portions furtherest from the windows at times when the space near the windows is quite adequately illuminated by daylight. Similarly lights used for special purposes only such as those on an individual machine should be controlled separately from the units furnishing general illumination.

Maintenance

A good lighting system once installed must receive a certain amount of attention regularly in order that operations carried on beneath it shall receive its full benefits.

A regular cleaning schedule must be maintained to control the deposit of grime and dust on reflecting surfaces. At the same time, burned out or blackened lamps should be replaced with new ones. Otherwise, the effectiveness of the system will be reduced just as surely as a cylinder that fails to fire will reduce a good automobile to the level of a poor one.

Lamp Voltage

Although 250 volt lamps are used on cranes and in places where only this voltage is available, the standard for lighting may be said to be 110 volts A. C. The greater safety of this low voltage is of course a major factor in its choice, but it also results in a more rugged lamp. Thus the filament wire used on a given size 110 volt lamp will be larger in cross section and therefore less likely to be broken or weakened by the vibration of buildings or fixtures with the passage of cranes and movement of other machinery.

The lamps used, must for greatest efficiency, be those manufactured for the actual voltage delivered at the lamp rather than the nominal voltage of the

system. Lamps are manufactured and marked specifically for use on 105-110 or 115 volts and if used on a voltage very much different from the one for which they are intended, their maximum effectiveness will not be realized. If used on a higher voltage their life will be shortened and efficiency reduced, while a lower voltage will also reduce their efficiency and since their light output is reduced as the square of the voltage the system will not deliver anything like the light intensity for which it was designed and of which it is capable.

Certain inevitable electrical power losses occur in the lines feeding a lighting system and they appear as loss of voltage. Thus the voltage at the power source or lighting transformer may be 115 but line losses may reduce this to 110 volts at one load point and at points further away to 105 or even 100, in just the same fashion as loss of water pressure occurs in long lines of small pipes. Adequate size of wires reduces this loss although it cannot be entirely eliminated.

So long as the feeder lines used supply only the amount and size of lamps for which they were installed the voltage at the lamps will usually be satisfactory, but if over a long period of time lights are added to it occasionally for new construction or those in use increased in size, feeders may be overloaded and both the voltage at the lamps and their lighting value considerably reduced.

This alone is responsible for the inadequacy of many lighting systems, and it is characteristic of steel plant construction that existing systems must be extended from time to time to take care of new work. It is desirable therefore to check periodically the voltage delivered to lamps in the system to consider how additions to the system will affect its voltage, and in a new system, to provide ample feeder capacity for present and probable future needs.

Announcement

Twenty-Sixth Convention and Iron and Steel Exposition
Association of Iron and Steel Electrical Engineers

June 16th - 20th, 1930

BUFFALO, NEW YORK

The Iron and Steel Exposition will be held in the Broadway Auditorium

Floor plans will be placed in the mail September First

APPLICATION of PULVERIZED COAL — TO — METALLURGICAL FURNACES*

By W. O. RENKIN†

ABSTRACT

There has been approximately 200 pulverized coal plants installed in connection with the Iron and Steel industry in this country.

These pulverized coal plants supply fuel to approximately 2500 furnaces of the following types:

Puddling and Busheling Furnace
Wrought Iron Pile and Faggot Heating Furnace
Ingots, Slabs, Billets and Rod Heating Furnaces
Forge Heating Furnaces
Rail Re-heating Furnaces
Continuous Heating Furnaces
Open Hearth Furnaces
Sheets and Pair Furnaces
Open and Box Annealing Furnaces
Malleable Iron Melting Furnaces

In the paper under reference the author has tried to give some useful information regarding results actually being secured rather than description of equipment.

The paper has been divided under the following headings:

1—Historical sketch of pulverized coal in Metallurgical work,—giving credit to Messrs. Lord and Culliney who did the pioneer work in this branch of the industry.

2—Types of Furnaces using pulverized coal—giving some descriptive data.

3—Fuel costs per ton of product,—giving some data on the preparation costs as well as relative costs per ton of steel heated with various fuels such as
Hand Firing with Bituminous Coal
Producer Gas Firing with Bituminous Coal
Fuel Oil Firing
Natural Gas Firing
By-Product Coke Oven Gas Firing and a curve chart showing the relative B.T.U.'s procurable for one cent.

4—Type of equipment required,—Giving a general description of pulverized coal plant operation rather than equipment details.

5—Advantages of Pulverized Coal Firing. Listing out under 10 points the advantages and benefits to be derived by using Pulverized Coal.

6—Furnace Efficiencies Being Secured,—Giving some data from actual operation.

7—Elimination of Early Difficulties,—Describing some of the early installation difficulties and explaining methods of overcoming same as found by experience.

8—Comparative outputs with Different Fuels,—Giving some examples of results obtained.

9—Conclusion. Giving some general information and comparative fuel costs.

*Presented before Twenty-fifth Annual Convention of the A. I. & S. E. E. at Pittsburgh, Pa., June, 1929.
†Combustion Engineering Corp., New York, N. Y.

Historical Sketch of Pulverized Coal In Metallurgical Work

This paper will deal with the use of powdered fuel in the iron and steel industry.

It is difficult to trace the early development in the use of pulverized coal, but it appears that the first experiments were made over a hundred years ago. In the early days of development, as also during the later years, one of the principal difficulties was in getting coal properly pulverized for successful use in metallurgical work. However, about 1895 success was obtained in the Portland cement industry. This gave impetus to the art, and several successful types of pulverizing mills were soon developed.

Early in 1903 Messrs. Lord and Culliney, of the American Iron and Steel Company, Lebanon, Pa., started operations in their plant. Considerable difficulty was experienced in taking care of the ash, and finally it became apparent that they would have to accept a slagging ash condition. Therefore, about 1905, they built a furnace so that the combustion

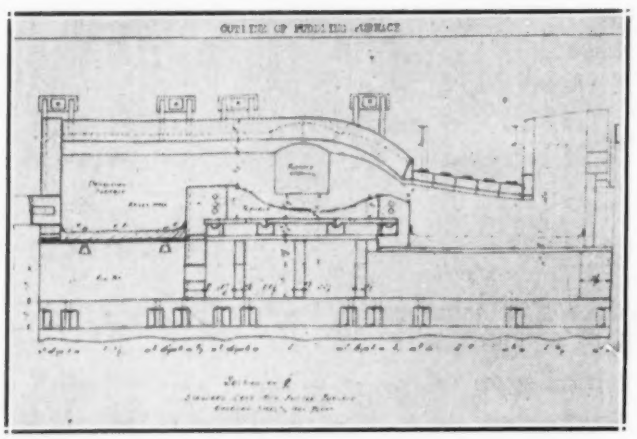


FIG. 1.

chamber floor could be dropped at regular intervals, after shutting down the furnace, and the slag removed in solid form. Since then, practically all metallurgical furnaces have been built so that the slag and ash can be removed during the week-end shut-downs. The success of this plant was kept more or less a secret until about 1912, when Mr. Lord presented a paper before the Engineers' Society of Western Pennsylvania which created considerable interest in powdered fuel for metallurgical work.

During the next few years several installations were made by various people, but another difficulty was found in the method of transporting the pulverized coal by means of screw conveyors and bucket elevators. The early installations were all fitted with drying equipment so as to reduce the moisture content of the coal before pulverization, and the method of conveying it made it almost impossible to maintain the plant and surroundings in a cleanly condition. In 1915, however, the fuel shortage and the need for greater steel output created a renewed interest in pulverized coal, resulting in the advent of compressed air transport and the circulating or air flotation system. These eliminated the difficulties of screw conveyor transport, and constituted a system that could be readily installed in existing plants.

In the past few years it has come to be realized that there is a vast difference between the burning of pulverized coal in boiler furnaces or cement kilns and its combustion in metallurgical furnaces. Successful operation in metallurgical work requires that the material being heated or melted shall not become contaminated. This requirement, which is not present in boiler firing practice, makes it necessary to have a clean flame and much more accurate control of the fuel. To insure these it has been found necessary to pulverize the coal to a more uniformly fine degree and to reduce the moisture content. For metallurgical work it has been considered standard practice to have the moisture content not over 1 per cent and the fineness such that at least 95 per cent will pass through a 100-mesh screen. For some operation, present day practice calls for 99 per cent through a 100-mesh screen, and a moisture content of 0.7 per cent.

Thus, advancement on the heating side of metallurgical work has heretofore been made in the preparation of the fuel and the method of burning it, rather than in the design of the furnace. Recent investigations, however, have led to some rather radical changes in furnace design, and as time goes on, developments along this line will no doubt show increases in economy as great as have hitherto been effected by changes in fuel and improvements in preparation equipment.

Heretofore the selection of fuel for metallurgical plants has, as a rule, been governed by local conditions. This has not always resulted in adopting the most efficient fuel. By-product coke oven gas is the most suitable fuel for heating furnaces, where it is available at a reasonable price. The use of coke breeze and anthracite coal in pulverized form has been found unsatisfactory for metallurgical work, as owing to the high cost of preparation and the lack of volatile matter, it is almost impossible to keep these fuels burning and to produce with them the commercially regulatable flame so essential to successful operation. American cannel coal has been used in emergencies, but when pulverized this fuel is hazardous to store. Some work has been done with peat lignite in pulverized form, but not sufficient to prove its value in comparison with bituminous coal. Some work has also been done with extra hard coal tar pitch, in pulverized form. This material cannot be stored for any length of time.

The standard fuel for metallurgical work, therefore, is bituminous coal. In most of the early installations the coal was not pulverized finely enough, and this necessitated high air velocity to carry it into the furnace. This, in turn, caused the coal and ash to carry over the hearth or precipitate on the material being heated.

Pulverized coal installations have become so standard that they are not considered any more liable to cause a shut-down than any other part of the plant. Pulverized coal, when properly dried, can be safely stored in bins at the furnaces for many months without danger of fire or deterioration. Trouble has been experienced with coal stored too long, however, so it is well always to try to use

up all pulverized coal before shutting down for many weeks.

TYPES OF FURNACES USING PULVERIZED COAL

Wrought Iron

Puddling and Busheling Furnaces

The first success with pulverized fuel in metallurgical work was attained in puddling. Since the early work done by the American Iron & Steel Company, many types of furnaces have been experimented with, and many puddling and busheling furnaces have been equipped for pulverized coal firing. The furnace developed by Mr. Culliney at the Lebanon installation, which has given fairly satisfactory results, is illustrated in Fig. 1.

In this furnace the puddler builds up a "monkey" on the bridge wall to suit conditions. The combustion chamber is fitted with a grate or floor made of flat bars arranged for ready dropping to clear out the ashes, this floor being covered with burned-out ashes to prevent the slagging ash sticking to the floor.

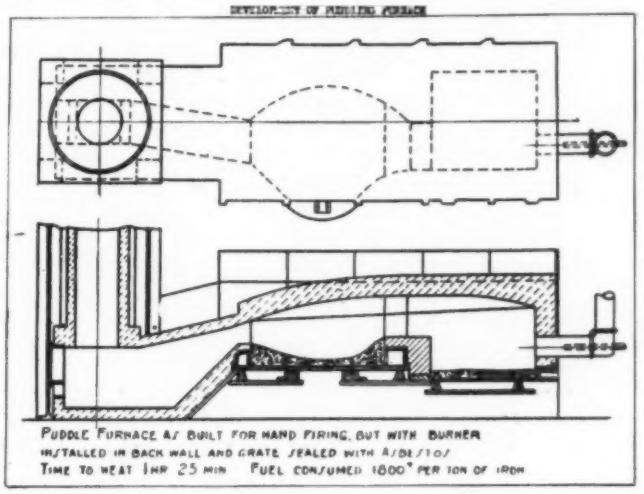

DEVELOPMENT OF PUDDLING FURNACE
PUDDLE FURNACE AS BUILT FOR HAND FIRING, BUT WITH BURNER
INSTALLED IN BACK WALL AND GRATE SEALED WITH ASBESTOS
TIME TO HEAT 1 HR 25 MIN FUEL CONSUMED 1800# PER TON OF IRON

FIG. 2.

It will be noted that in the earlier furnace shown above, the roof over the combustion chamber was level, whereas in the design shown in Fig. 2 the roof rises in a half arch from the back wall to about the center of the combustion chamber. This shape of roof seems to give a much better control of the flame and is now practically standard for puddling and busheling furnaces, both pulverized coal and hand fired.

The wide range of flame conditions, from highly reducing to intensely oxidizing, which the puddling furnace requires, is met most satisfactory by pulverized coal. The temperature range of the puddling cycle is indicated in Fig. 3.

The fuel saving by using pulverized coal instead of hand-firing is large, and in addition, the reduction of time per heat makes it possible to secure five full heats on each eight-hour turn. With pulverized coal firing, all the air needed for combustion enters the furnace through the burner opening and, like the coal, is under the puddler's full control at all times. The Culliney burner shown on the last furnace scheme referred to above, is designed for a minimum of primary air (about 30 cu. ft. per lb. of coal at maximum fuel needs) to carry the coal from the feeder to the burner, and for a discharge velocity of 4,000 ft. per minute at the maximum feed. The secondary or combustion air is supplied under controllable pressure through the burner elbow at a velocity of not over 3,500 ft. per min. at maximum coal feed. The coal-laden primary air entering through the center is absorbed into and softened by the lower-velocity secondary air, and the two readily mix to give the required flame.

Data secured from several plants show fuel consumptions per gross ton of muck bar produced in

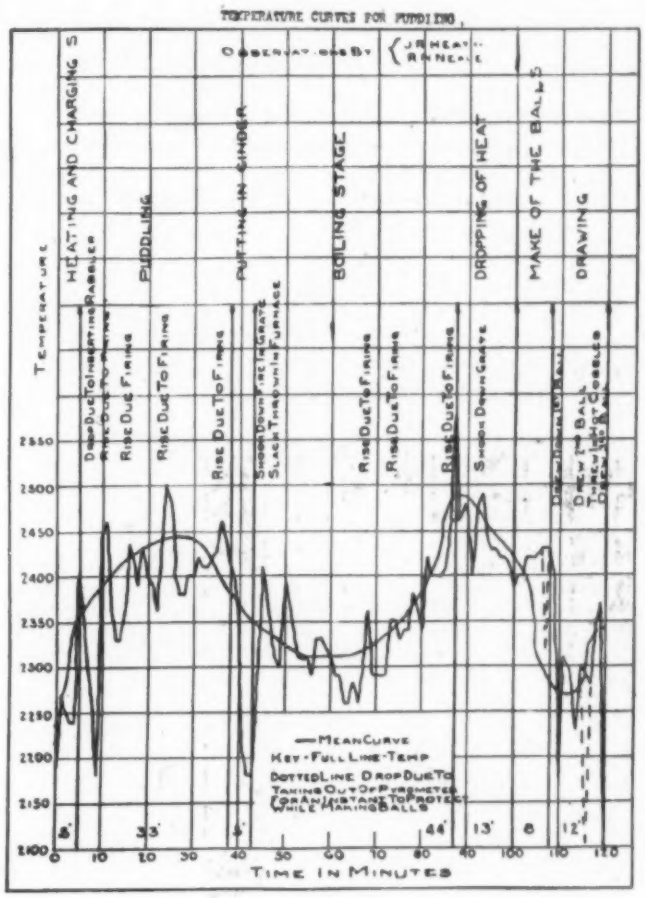


FIG. 3.

this type of furnace when fired by hand, by natural gas, and by fuel oil, as follows:

		B.Th.U.
Coal (14,000 B.Th.U. per lb.)		
hand fired ...	2,740 to 32,33#	40,600,000
Natural gas fired..	25,000 to 32,000 cu. ft.	27,399,600
Oil fired	226 to 240 gal.	31,185,000
Pulverized coal fired	1,890 lbs.	25,150,000

The fuel saving of pulverized coal over hand-firing is, therefore, approximately 37 per cent. The above figures are for puddling hard pig and producing the very best quality hand-puddled wrought iron, on softer and lower grade iron the fuel consumption is lower, but the saving by use of pulverized coal has been found to be approximately the same.

The operation of busheling furnaces has shown similar marked economy, the average fuel consump-

tion per gross ton of muck bar produced being as follows:

Hand-fired .....1,000 to 1,290 lbs.
Pulverized coal-fired ..... 650 to 730 lbs.

When working on scrap the fuel consumption for each of the above operations is considerably less. The proximate analysis of the coal used is as follows:

	Hand Firing Per Cent.	Pulverized Per Cent.
Fixed carbon	53.20	52.92
Volatile matter	36.32	33.17
Ash	9.13	11.33
Moisture	1.35	0.98
Sulphur	1.24	1.62
Heat Value (B.Th.U. per lb.) 14,000		14,100

Wrought Iron Pile Re-Heating Furnaces.

At the present time all wrought iron is made by the puddle mill producing muck bar which is cut up into suitable lengths and tied with wire into piles or else by scrap filled box piles and Faggots which require to be heated above the welding temperature then rolled into the desired shape.

Probably 90 per cent. of this class of work is done in single end reverberatory sand-hearth type furnaces. A few regenerator type, producer gas-, oil, and natural gas-fired furnaces are still in use,

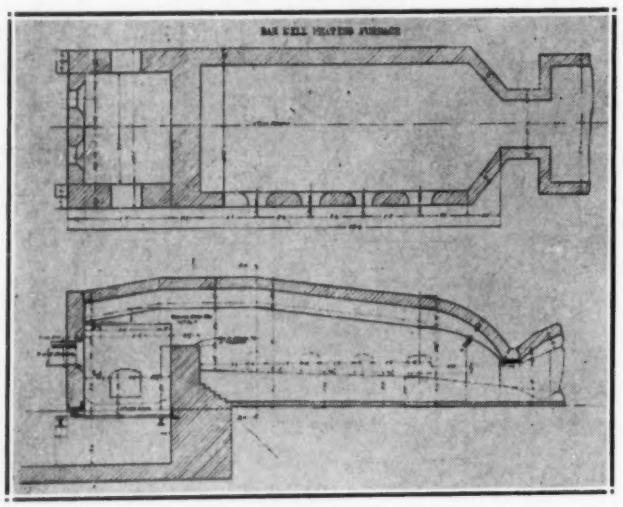


FIG. 4.

however. Accurate control of fuel mixture and flame must be readily securable at all times, in order to permit the attainment of the high temperature necessary to have the piles above the welding temperature when they strike the rolls.

Average fuel consumptions per gross ton of iron heated in this class of work are as follows:

Coal, hand fired .....1,100 lbs.
Natural gas fired .....17,550 cu.ft.
Fuel oil fired .....110 gal. (U.S.)
Pulverized coal .....445 lbs.

With regenerator producer-gas-fired furnaces a fuel consumption of 477 lb. of coal per gross ton of finished skelp produced has been secured under certain conditions. Using the same coal in pulverized form in non-regenerative reverberatory furnaces, the following results were secured:

Coal per gross ton charged.....475 lbs.
Coal per gross ton skelp produced..514 lbs.
Coal per gross ton produced and recoveries .....422 lbs.
Furnace loss .....7½ per cent.

Figure 4 shows the usual type of sand hearth pile reheating furnace arranged for pulverized coal firing.

This cut shows the drop grate ash slagging combustion chamber.

Our later experience leads us now to increase the length of combustion space between the burner and bridge wall to 8′0″ so as to prevent the burning particles being carried over and falling on the material being heated.

MELTING FURNACES

Iron Blast Furnaces

Considerable work has been done in this branch of the industry but difficulty has been encountered in getting the pulverized coal to burn and not precipitate.

Pulverized coke has so far not met with any success and coke with ore dust mixtures have so far met with no success.

However, it has now been found possible to feed the pulverized coal directly into the proper part of the blast furnace, thus overcoming, it is believed, the mechanical difficulties which have heretofore prevented proper injection of the coal. No doubt the next few years will see this fuel being substituted for 30 to 40 per cent. of the coke now used. The introduction of fuel having a known analysis directly at the melting zone will, no doubt, prove a distinct advantage in correcting errors in mix immediately, instead of after some hours, as in the present practice.

Air Furnace

There are many plants in which the melting is done with pulverized coal, and the furnaces for such fuel have been developed to a very high stage of efficiency. In the plant which holds the fuel-ratio record of the United States, 3.8 pounds of iron are melted with each pound of pulverized coal fed to the furnace or 7,430,700 B.Th.U. in the fuel per 2,000 pounds of iron melted. The proximate analysis of the coal used at this plant is:

	Per cent.
Volatile matter	34.8
Fixed carbon	59.0
Ash	5.5
Moisture	.7
Sulphur, separately determined, less than	1

In addition to the exceptionally good fuel-ratio secured by fine grinding and proper drying, combined with an efficient burner arrangement, there has been noticed a decided improvement in the elimination of carbon and sulphur additions to the bath.

Practically all air used for combustion of pulverized coal in this industry is at atmospheric temperature, and the present rapid development of suitable air heaters, using the furnace waste gases as a heating medium, will greatly assist in further reduction of fuel consumed.

The burners for directing the pulverized coal into the furnace are simple in construction, consisting of

a square-turn elbow through the center of which the coal and primary, or carrying-air, pipe passes. The additional air needed for combustion enters through the annular space between the coal pipe and the surrounding walls of the burner elbow. The air for combustion is regulated by means of a blast gate in the line. Experience has shown that the velocity of discharge of both the primary and combustion air should be 4,000 ft. per min., and that the quantity of primary air carrying the coal from the feeder to the burner should be 60 cu. ft. per lb. of coal, when feeding the maximum amount of fuel.

Open Hearth Furnaces—Steel

Owing to the early difficulties encountered with pulverized coal and the high state of development of these furnaces for gaseous and liquid fuels, there has been little incentive to push pulverized coal as a fuel for this work. However, the experiences of plants operating with pulverized coal show that this fuel can be used successfully and with a considerable saving over oil, natural gas, or town gas.

The open-hearth plants that have been using pulverized coal report successful operation, with fuel consumptions ranging from 450 lb. to 600 lb. of coal per ton of steel.

The Eastern Steel Company's plant at Pottstown, Pennsylvania, was described in a paper presented by Mr. Herndon before the spring meeting of the American Society of Mechanical Engineers, held May 14th to 17th, in Pittsburgh, Pennsylvania. At this plant it has been found that a coal having a higher ash content can be used by grinding more uniformly and drying better.

Early troubles with checkers becoming clogged and deleterious additions of sulphur, as well as ash, to bath prevented the proper advance of this fuel.

We have, however, found that these difficulties were mainly caused by improper preparation of the fuel and so today we are going ahead in this branch of the industry.

By properly preparing the coal, getting it pulverized so that a sufficient percentage will pass through a 100 mesh screen, with the minimum amount of impalpaple powder, we find that the sulphur and ash do not precipitate on the bath, but are carried over into the slag pockets at ends of furnace.

By elimination of checker bricks and the substitution of simple arches it is possible to secure sufficient preheat in the combustion air and get better control of furnace at all times.

There are many plants using other fuels that can advantageously be changed to pulverized coal firing.

It is confidently predicted that within the next few years open-hearth furnaces will be developed which will utilize finely pulverized coal at a fuel consumption of about 400 lb. or less per ton of steel heated.

Re-Heating Furnaces—Steel
Hearth Type Side Door Furnaces

There are many installations of this type furnace both in single-end-reverberatory and double-end-reversing design that are giving most excellent results.

Generally speaking, the range in size of material heated in this type of furnace is so great that good efficiency cannot be secured yet in furnaces heating billets weighing 150 lbs. to ingots weighing 11,000 lbs. the fuel consumption ranged between 350 and 450 lbs. of coal per gross ton heated.

In one plant where the range is not so great and the size of material heated being from 4" square to 8" square the fuel saving as compared to producer gas was 100 lbs. of coal.

Forge furnaces heating slabs and ingots for heavy forge work where the material must be given two heats shows fuel consumption of 600 lbs. of coal per gross ton including the production of approximately 100 boiler H. P. of steam.

Continuous Type Furnaces

These are generally of either the End discharge or Side discharge type.

Experience has shown that length of skid pipe from Knee to cold end wall and the width of furnace determine the output capacity of furnace but the kind of fuel used greatly effects this output.

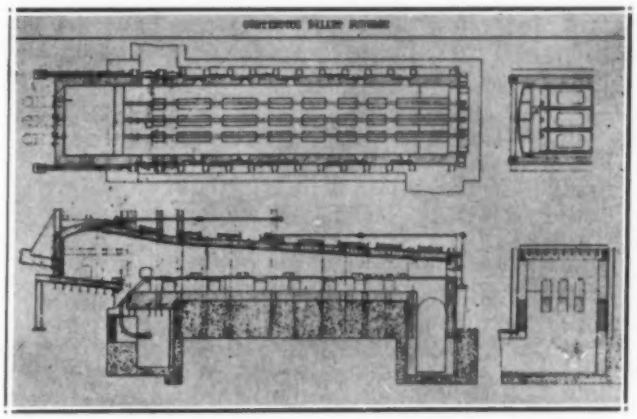


FIG. 5.

In properly designed furnaces, pulverized coal will give the maximum output. This sometimes means an increase in output over other fuels as high as 60 per cent.

The heating of steel billets, blooms and slabs requires a mellow flame, with minimum luminous streaks, as this is the type of flame whose heat will penetrate the steel with the minimum surface damage and insure the quickest, most uniform heat throughout.

Furnaces using pulverized coal require a lower damper than with other fuels so as to keep the furnace well filled with heat.

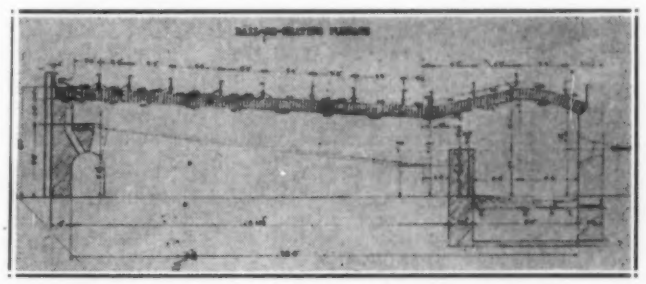


FIG. 6.

Furnace design should be such as to insure practically complete combustion before the gases cross

the bridge wall and roof shape should be so designed as to insure the proper position of hot spot.

Flat roofs of the suspended type give a more uniform heat across the furnace width than do arch roofs.

Wherever possible combustion chamber should be so placed that a portion of the heat can travel under the steel.

Figure 5 shows the lines of an End discharge type furnace and

Figure 6 shows a Side discharge type.

In one plant the plate mill furnace heating steel from 2⅞" to 13⅞" thick showed average fuel consumption of less than 300 lbs. per gross ton heated over a month's run.

Another furnace heating billets from 3" to 4¼" thick showed an average for several months of 200 lbs. of coal.

Billet heating furnaces run as low as 143 lbs. of coal per gross ton heated.

All the above figures are based on cold stock heated to 2200°F.

In one plant where a test was run on Slabs weighing 1760 lbs. each with coal dried to less than 1% the fuel consumption was 117 lbs. per gross ton heated and the output 17,600 lbs. per hour as against with undried coal a fuel consumption of 172 lbs. and output of 14,040 lbs. per hr.

The fuel consumption per ton of material heated is effected by the relation of length of skid pipes to thickness of steel being heated consequently all installations differ and output must be given consideration along with fuel efficiency.

In the heating of steel rails pulverized coal has been very satisfactory and fuel consumption of 180 pounds per ton over several months of single turn operation are being secured.

Furnaces heating one thickness of billets can be designed to operate very efficiently and owing to the simplicity of furnace design the first cost and maintenance are the lowest.

Sheet and Pair Heating Furnaces

In this branch of the industry owing to the need for low temperature flame control the central plant bin system has proven the most successful.

There have been many pulverized coal installations in this industry, and pulverized coal is today in successful use alike for high-grade, full-finish, and ordinary sheets. Combination sheet and pair heating furnaces on ordinary-finish, or tight iron, are successfully producing sheets with 160 to 180 lb. of pulverized coal per net ton of sheets.

Continuous type pair heating furnaces are in general use and give exceptionally good results. In one eight-hour turn, one mill, using pulverized coal, heated and rolled 400 pairs of bars 8" x ¼" weighing 16,320 lbs., and put 1,600 sheets, 30 ga., 36" x 72" weighing 11,780 lb. into warehouse without any wasters or cut downs. The same mill heated 744 pairs weighing 22,989 lb. On another eight-hour turn, and on a third it heated 546 pairs weighing 23,840 lb.

Sheet furnaces of the double chamber type are operating successfully on pulverized coal, with an average fuel consumption of 151 lb. of pulverized coal per net ton of sheets heated. At the pulverized-coal-fired plant 356 lb. of coal per net ton of steel heated were required for sheet-and-pair-heating and annealing. The above results were all obtained on the production of tight or ordinary finished sheets. For the production of full-finished high-grade sheets especially designed furnaces are required, and the fuel consumption is slightly higher.

Proper preparation of the coal and furnace design are the main requisities along with correct velocity of coal feed that make a successful plant.

Annealing Furnaces

There are some open flame and continuous type sheet annealing furnaces using pulverized coal successfully but the principal use of this fuel is in connection with Box annealing furnaces.

In the annealing of Malleable casting fuel ratios of 5 to 1 are being secured with practically all good castings.

Sheet annealing for both tight and full finish as well as electric steel is being done successfully in many plants.

Fuel consumptions of 140 to 182 lbs. per ton of sheets are being secured.

Increase in life of boxes helps to reduce the cost of annealing.

Box annealing furnaces in successful operation are of the single Box double chamber, as well as double box double chamber type.

Fuel Cost Per Ton of Product

With properly designed furnaces, Pulverized Coal will operate at least on an equal B.T.U. basis with oil or natural gas and generally will do the work better.

The cost of preparing, storing, feeding and burning pulverized coal will add from 45 to 70 cents to the price of the coal as delivered.

For pulverized coal it is possible to use slack and screenings, making a saving in raw fuel cost of from 50 cents to $1.75 per net ton delivered.

The actual fuel saving by changing from other methods of coal firing to pulverized coal amounts to from 20% to 40% of the actual heat units.

Increased output due to more effective heating and reduction in furnace loss are other rather important items in reducing fuel cost per ton of output.

In one plant changing from Oil to Pulverized Coal cut the cost per ton of product 50%.

On the basis of slack Bituminous coal per net ton delivered of $3.00 the cost of pulverized coal as burned at furnaces (including fixed charges) would be $4.00.

Assuming a heat value for this coal of 12,800 B.T.U. per lb. we then have the following comparison with other fuels.

Heating 4" sq. Billets to 2200° F. in a continuous furnace (Per gross ton steel heated):

	Lbs.	BTU	Cost
Pulverized Coal as above	220 lbs.	2,560,000	$0.40
Hand fired (Coal at $4.00)	320 lbs.	4,432,000	0.64
Producer gas (Coal at 4.00)	275 lbs.	3,808,750	0.62
Oil (Per gal 2.8 cts.)	25 gal.	3,500,000	0.75
Natural gas (at 1000 B.T.U.)	3500 cu.ft.	3,500,000	1.05
By product gas (coke oven)	6000 cu. ft.	2,688,000	0.60

Please note that = A preparation and burning charge of 50 cents per net ton of coal gasified has been added to the Producer Gas and a charge of ½ cts. per gal. for oil.

Natural gas has been put in at 30 cts. per 1000 cu. ft. and by-product coke oven gas 10 cts. per 1000 cu. ft. on basis of 450 BTU per cu. ft.

The ability to use the lower grade coal in pulverized form makes an even greater saving possible in Basic open hearth furnaces as in one plant under consideration the change in grade of fuel alone means a saving of 70 cents per gross ton of Ingots produced which would pay for the coal preparation cost and still leave a nice return on the investment.

Curve Chart Fig. 8 gives the comparative B.T.U.'s per one ct. with various fuels.

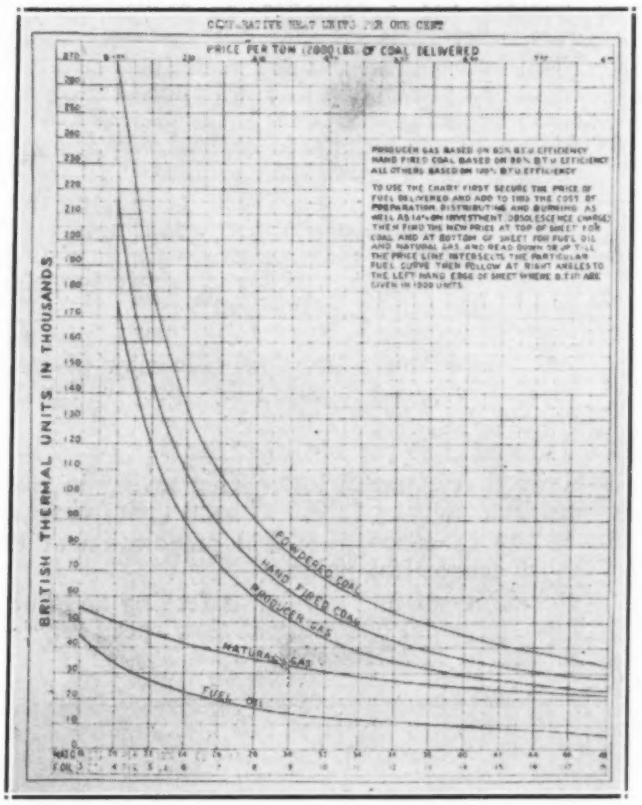


FIG. 8.

TYPE OF EQUIPMENT REQUIRED

Although there are places where pulverized coal without separate drying and fine pulverization is very successfully used, yet our experience has convinced us that in general this industry requires coal finely ground and properly dried.

To secure the greatest efficiency and flame control, regulation of the fuel at the point of use is also a necessity.

We, therefore, recommend the Central Preparation Plant Bin System Installation for Metallurgical Work.

In such a system the coal is crushed, or received in size suitable for preparation, usually to pass through a 1" ring.

The coal as received is elevated to a storage bin from which it is fed to a rotary dryer where the hot gases do not come in direct contact with the coal and the surface or Hydroscopic moisture is reduced to less than 1%. For Melting furnaces and low temperature furnace work this is reduced to about 7/100 of 1%.

This drying is necessary to insure the coal going to furnace of proper fineness and also to assist in pulverization.

The dried coal is then delivered to Pulverizers of the air separation type where it is pulverized to the required fineness with the minimum amount of impalpable powder possible. Our experience has proven that control of flame is best secured with coal pulverized in an air separation mill where the air enters the mill below the grinding zone.

In the case of high sulphur or high ash coals, fine grinding is of considerable importance.

For Melting furnace work and low temperature furnaces or furnaces using small quantities of coal per hour, the coal should be pulverized so that at least 98½% will pass through a 100 mesh screen and the minimum commercially possible through a 300 mesh as the impalpable powder causes streaks and flashes in the flame.

For heating furnace work best results are secured with the coal pulverized to pass not less than 96 per cent through a 100 mesh screen with good coal, and relatively finer on coal of poor quality.

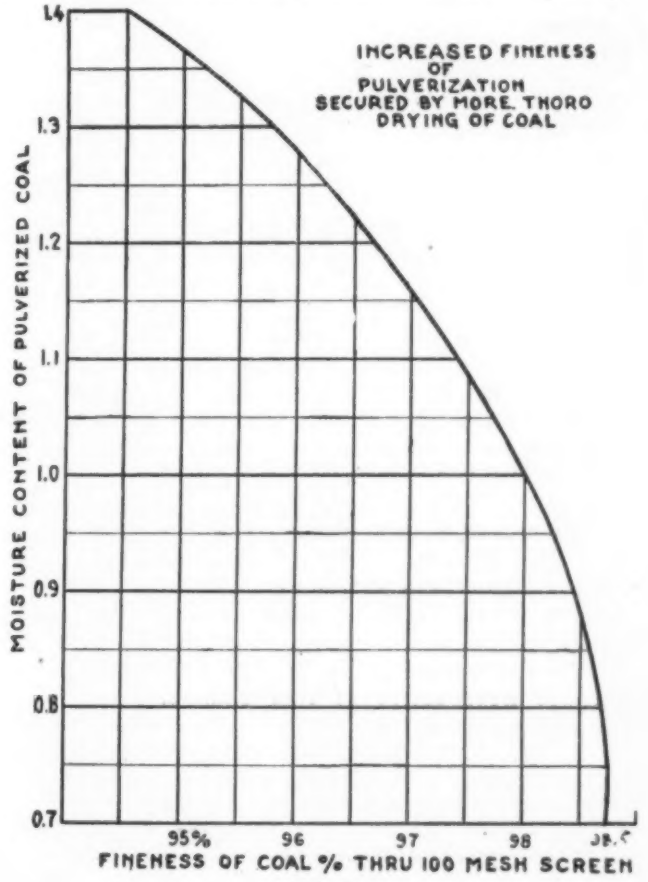


FIG. 9.

As fineness of the coal going to furnace is necessary to secure the best efficiency, we have found that even though the coal is pulverized sufficiently fine, yet if not properly dried, the particles become packed and agglomerate in passing through feed controller or regulator, so that we have found when

coal has 1.4 per cent of moisture leaving pulverizer and ground to pass 99.2 per cent through a 100-mesh screen, this coal went to burner as only 99 per cent, passing a 100-mesh screen, while coal containing only 8/10 of 1 per cent of moisture, pulverized to the same fineness, went to burner with 99.1 per cent passing through 100-mesh screen.

Figure 9 shows the advantages of better drying in increased fineness of output.

The pulverizers then deliver the coal to a transport unit of the compressed air blow tank type, without moving parts, which transports the coal through standard weight steel pipes to the various storage bins placed adjacent to the furnaces.

The transport pipe line can be run overhead or buried in the ground and requires no paralleling compressed air blow out line.

The quantity of air used to transport the coal is approximately 1½ one thousandth of that necessary for combustion.

The storage bins at furnaces usually have from 12 to 16 hours' supply for their respective furnaces.

These storage bins are all provided with full bin signal connected by signal system with preparation plant so as to prevent overfilling of any bin.

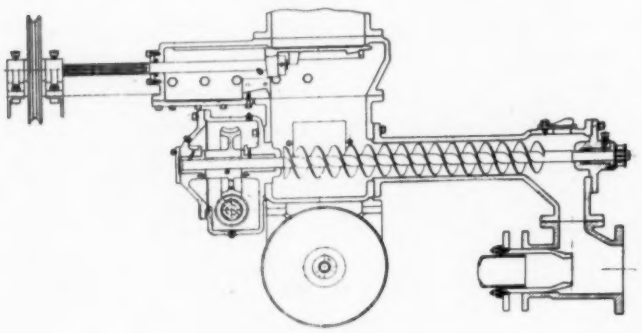


FIG. 10.

Each bin is fitted with dust tight discharge gates and a separate feeder for each furnace burner so as to give the furnace operator complete control of the flame and fuel conditions.

For the open hearth furnaces a compressed syphon feeder has been found to give the best results as it is the simplest and permits of almost instantaneous starting and stopping.

The quantity of air needed to feed the coal is so small that it can be maintained at constant velocity thereby insuring the position of the hot spot in furnace irrespective of fuel change.

In the early open hearth installations the velocity of fuel entering the furnace was too high and we now know that it should be approximately 8000 ft. per minute for this work.

In the case of heating furnaces the velocity should be 4000 ft. per minute.

The length of combustion space needed to properly burn pulverized coal prepared and dried as described before, is 2' horizontally for each 1000 ft. per minute velocity of discharge from burner tip.

Burners should be of the simplest straight flow type as the vertical space available in most furnaces does not permit of a turbulent type burner.

Figure 10 shows the latest type coal regulating feeder for heating furnace work. This type feeder operates at slow speed and has a maximum capacity of 1250 lbs. per hour.

Figure 11 shows the type of feeder recommended for larger capacity. The stream of coal can be sent to one burner as indicated or to two separate burners in the same furnace as there is a separate regulating shutter on each outlet.

A plant with equipment as outlined will not only insure the greatest efficiency but will also be dustless and safe to operate.

ADVANTAGES OF PULVERIZED COAL FIRING

As pulverized Bituminous Coal permits of the widest range in flame condition it is naturally the best all around fuel for heating and melting problems.

In general the advantages of pulverized coal firing over other fuels is:

1—Reduction in fuel per ton of output.
2—Increased production due to better heating and flame control.
3—Ability to use low grade coal when price warrants or other conditions require.
4—Ability to secure any type of flame, from highly oxidizing to intensely reducing.
5—Lower furnace maintenance resulting from simpler construction and the relatively softer heat produced by pulverized coal.
6—High temperatures can be obtained easily, and low temperatures at high efficiency of combustion can be secured by proper furnace design.
7—Reduced cost per ton of output.
8—Reduction in metal loss. This saving in some cases amounting to 3% of total metal charged.
9—Ability to concentrate fuel preparation at the most economical point.
10—Reliability of fuel supply, as feeding and burning equipment operating at slow speed requires minimum of attention.

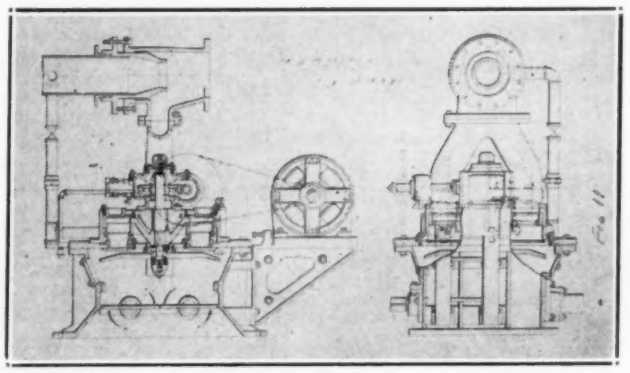


FIG. 11.

FURNACE EFFICIENCY BEING SECURED

There are so many factors entering into this question that any statement made must be general.

However, in heating furnaces fired with pulverized coal actual B.T.U. efficiencies of 35% are being secured under favorable conditions and 28% in daily operation.

Figure 12 gives the heat content of iron and

steel at various temperatures and from this chart we find that mild steel requires 363 B.T.U. per lb. at 2200 degrees F.

This means 813,120 B.T.U. per gross ton of steel and assuming a starting point of 70 degrees we have for the net heat needed 768,320 B. T. U.

At 28% overall efficiency the actual heat needed will be 2,744,000 which at 13,500 B.T.U. per pound of coal is 203 lbs. of coal per gross ton of steel heated.

With the addition of simple type air preheaters the combustion air can be brought up to about 560 degrees F. and an actual fuel saving of at least 10% be secured.

In a single end fired furnace it is not advisable to heat the combustion air above 560 degrees F. as the length of combustion space required to permit the coal to get sufficient oxygen for proper combustion increases greatly above this point.

A discharge velocity of approximately 4000 ft. per minute is necessary to maintain control of the flame and prevent precipitation of unburned coal.

Figure 13 shows the relation of combustion air temperature to velocity of combustion and length of combustion space required.

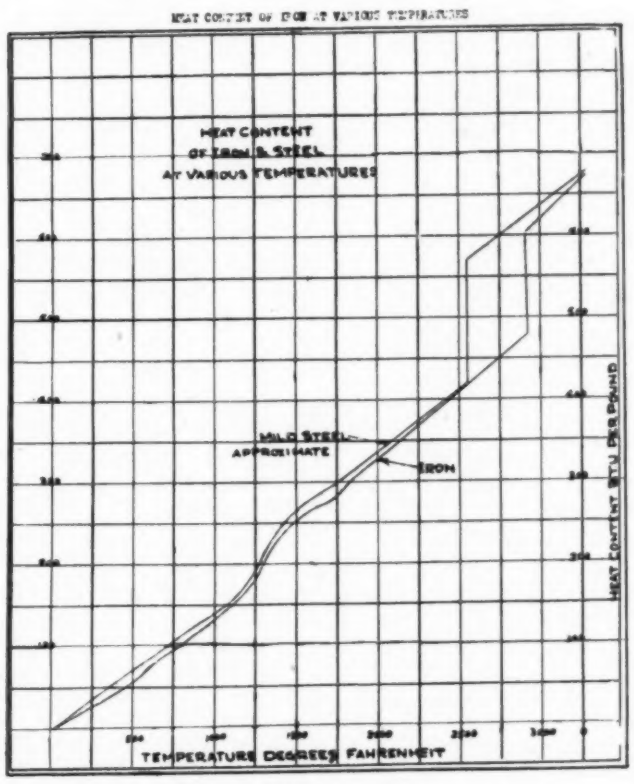


FIG. 12.

ELIMINATION OF EARLY DIFFICULTIES

In many of the early installations much grief was experienced and it has taken time to find the reason for the difficulties encountered so as to plan out the way of their elimination.

One of the most annoying troubles in the early installations being packing and arching in the bins then the coal suddenly slipping and causing a flood of fuel to the burners.

Caking and packing in the feeders is also one of the early troubles that interfered with fuel regulation.

Aglomeration of the coal particles, after having been properly pulverized, as they went to burner is another of these griefs.

By properly drying the coal we have been able to practically eliminate the mechanical troubles and pulverized coal can now be stored in bins for months with no apparent change in condition.

The better drying of the coal has permitted more uniform control of pulverization which has in turn overcome the early burning difficulties.

By finer pulverization it has been possible to prevent precipitation of unburned particles.

Experience has also taught us the proper feeding velocity of the pulverized coal as well as the velocities that should be maintained in furnaces for various purposes.

In some of the early melting furnace installations velocities as high as 16,000 ft. per minute were used to carry the coal through the furnaces while in heating furnaces the combustion chamber were built so short and the burners placed so low that the coal stream would cut through the bridge wall frequently in 48 hours.

Intensely hot spots on roof were encountered in some heating furnace installations due no doubt to the excess of impalpable powder.

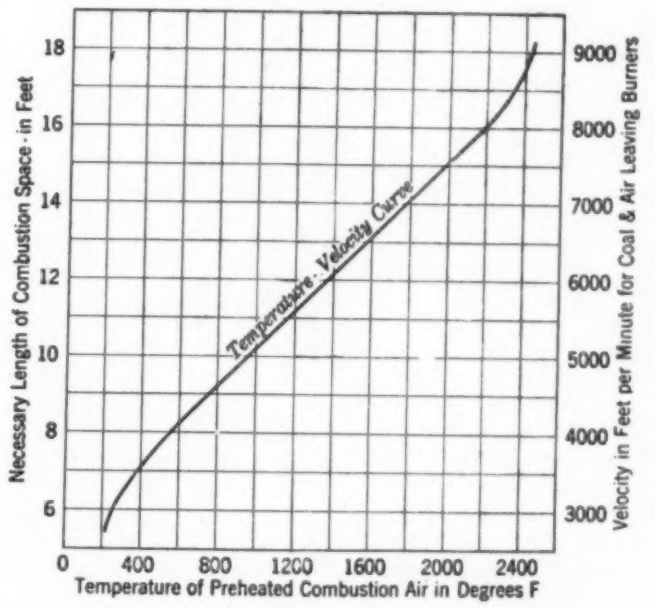


FIG. 13.

Coarse coal, requiring high velocity to prevent precipitation, was the cause of ash deposits on the material making stains that caused rejections.

High maintenance and wear and tear on all equipment was principally eliminated by proper drying.

Early feeders were also hard to control as the direct current motor regulators only had 12 points of control and although the speed change was not much yet the fuel change per step was so great that the furnace operator spent much of his time "putting coal on and taking it off."

With the modern motor speed regulators having 100 points of control this early difficulty has been eliminated.

Early furnace design gave considerable prominence to "Heating by convection" and although this is true of some fuels, it is not so with pulverized coal.

In heating with pulverized coal the most beneficial heat is secured by radiation in fact in a continuous heating furnace the heat input to the steel by convection is less than three percent and practically constant for the entire furnace length while the heat input from radiation is about 87 per cent at the hot end.

The Heat Economy Bureau of the German Iron and Steel Institute made a series of tests on a pusher type continuous heating furnace which gave some interesting data.

COMPARATIVE OUTPUTS WITH DIFFERENT FUELS

Output is generally increased by changing to pulverized coal and in some installations this increase is very considerable.

1—Rail reheating furnaces changed from hand firing to pulverized coal firing showed an increase of practically 60%.

Hand firing.....10 net tons
Pulverized coal firing.....16 net tons

2—Billet reheating furnace changed from By-product coke oven gas fired to pulverized coal firing.

By-product coke oven gas....20 g. tons
Pulverized coal firing.....28 g. tons

3—Slab reheating furnaces changed from Producer gas to pulverized coal firing.

Producer gas firing.....22 g. tons
Pulverized coal firing.....28 g. tons

4—Average increase in ingot output by changing open hearth furnace from Oil to Pulverized coal 14%.

5—Pile reheating furnaces changing from Natural gas firing to Pulverized coal firing showed an average increased output of 18%.

6—Sheet mill furnaces changed from hand and stoker fired to Pulverized coal firing showed increased output on tight iron 40%.

Conclusion

There are conditions where pulverized coal will probably never be adapted to, but in general it is the most efficient in the industry referred to in this paper.

In many of the installations under consideration the savings assured by changing to pulverized bituminous coal will completely pay for the entire improvement including necessary furnace changes in from one to two years.

One project calling for the change from liquid tar at 5½ cents per gallon to pulverized coal, with raw coal at $3.05 per net ton delivered shows a complete return of the investment in 10 months of normal operation.

A comparison of prices permissible for other fuels and based on pulverized coal will no doubt be of interest:

To secure the equivalent heat units for one cent with other fuels as with pulverized coal they must not cost more than the following prices. (Note—A preparation charge of $1.00 is added to the coal for pulverization making cost at furnace $4.00).

1—On basis of raw coal delivered at Preparation plant (13,500 BTU per lbs.).....$3.00
2—Oil per gallon including atomization.....02
3—Natural gas per 1000 cu. ft. based on heat value of 1000 BTU per cu. ft.....14-8/10 cts.
4—Producer gas—allowable price of raw coal as received per net ton.....$2.00
5—Hand Firing Coal per net ton delivered at furnaces $1.34
6—Coke oven gas per 1000 cu. ft. at furnaces. (Note—No allowance made for expense of feeding and burning).....6-2/3 cts.
7—Tar having 180,000 BTU per gal. Price per gal. delivered (including all costs of heating, feeding and burning).....2-2/3 cts.

A quotation from a plant owners published amount of the results obtained and benefits derived should be a fitting end to this paper.

"The substantial reduction in costs, due to powdered coal, cannot be measured by a comparison of the direct costs only, such as fuel and labor, as the collateral benefits of this important installation are many. Lower costs when the mills are operated intermittently, lower furnace maintenance, elimination of ash handling, lower operation labor costs around the furnaces, stimulation of production due to increased heating capacity, better heating and improvement in quality, all can be attributed to the use of pulverized coal.

"Powdered coal enabled the organization to solve a difficult problem as, in addition to the urge of economic necessity and with civic pride aside, the company was confronted with a recently enacted city smoke ordinance. While receiving the co-operation of the Bureau's Inspectors, the terms and conditions of the ordinance were unmistakeable. The plant is located in a thickly populated section. The disappearance of the black smoke, due to the use of powdered coal, and the noticeably cleaner atmosphere are welcome to the citizens, as well as meeting the requirements of the smoke ordinance."

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*Cranes for Steel Mills**

By J. MATTHEWSON†

The development of cranes for the steel mill has kept pace with other improvements in the steel industry. This development was made possible by the co-operation of the steel mill engineer and the crane builder.

Efforts have been made to reduce hazard by safe guarding the crane in every possible respect, and the necessity of reducing production costs of steel dictates the maximum in reliability and the minimum in maintenance.

*Presented before Chicago District Section of the A. I. & S. E. E., April, 1929.

†Gen'l. Supt., Alliance Machine Company, Alliance, Ohio.

Steel mill service requires a crane of heavy, rigid construction, and the one piece trolley design featured by the Alliance Machine Company has met with much favor.

The first crane that was installed with this type of trolley was built for an Eastern Steel Mill. They required a 25-ton crane with 10-ton outer hoist for cleaning up in their Open Hearth of seven furnaces, which required very severe service. This one piece trolley for this crane was designed at the suggestion of these engineers to meet their requirements. This particular trolley was installed April, 1923, and so far we have had no failures from this crane.

In this design the trolley sides, connecting frame, and bearing brackets are contained in one steel casting, making the most rigid construction possible, with nothing to work loose or get out of line. The one piece trolley is applicable to all classes of cranes and is much used for heavy standard types, as well as for special machines such as Soaking Pit cranes and open hearth chargers.

We have 150 of these cranes running satisfactory and 63 of these going through our plant at the present time.

Hardened and heat treated gears and pinions are being quite largely used, greatly increasing the life of those vital parts. Steel drums are also being used to a considerable extent. There is a difference of opinion among steel mill engineers as to the comparative effects of steel and iron drums on the life of the hoisting cables, and definite data on this subject would be of interest to both the manufacturer and the user.

The crane safety requirements of the steel industry are well understood and will be mentioned only in so far as they affect modern crane design.

Over hung gears have been practically eliminated from the modern crane, and we note the development from the exposed gear to the guard, and finally to the totally enclosing case, preferably oil tight, affording both protection for safety and lubrication for long life.

The possibility of running the gears in an oil bath leads to a consideration of the worm gears as a means of speed reduction.

The worm gear was formerly considered an unreliable and inefficient mechanism, to be employed only when no other speed reducing means could be used to advantage. There were, however, some noteworthy successful applications, indicating possibilities for general use.

The automotive engineers recognized this possibility, and the necessity of a reliable, compact, right angle, high reduction unit for the rear axle drive for motor trucks, developed the modern type of worm gearing, using a hardened and ground steel worm and a bronze worm wheel.

The success of this drive, due to proper design and materials, under the severe service of motor truck usage, led to the development of a similar type for general commercial use, and to a serious consideration and investigation by the engineers of the steel mills and the crane manufacturers, as to whether the modern type of worm gear reduction was suitable for crane usage. The result has been a marked change in attitude by the engineers, and their recommendation, in many cases, of the worm drive in preference to other established types of gear reductions.

It was found that, except in the case of extreme reductions, if proper design, materials and workmanship were used, the efficiency of the worm gearing was greater than that of ordinary spur gearing giving equal reductions, and that longer life and lower maintenance were to be expected. The results have justified these expectations.

The efficiency of the worm gear is of course dependent on the helical angle of the worm thread, and as dynamic braking is usually used in the hoist motion of a crane this point must be given consideration.

Extreme reduction should be avoided as the efficiency decreases rapidly and, as the helical angle becomes small, there is a tendency toward self-locking which might prevent the load from overhauling the gearing.

For crane usage the worm can be placed either above or below the worm wheel with equally satisfactory results.

The first installation of the modern type of worm gear made by our company was 21 units on car dumping and vessel loading equipment for the Virginian R. R. at Norfolk. This was put into service in 1924 and has given perfect satisfaction.

The first crane installation made by our company was at the Ford Motor Company's plant in 1925 and has given equally satisfactory service.

Notable installations using the modern type of worm gear which are being, or have recently been made by our company as as follows:

Timken Roller Bearing Company—One 165-ton ladle crane with worm driven main hoist, and one 5-ton low floor type open hearth charging machine, having a worm drive on the hoist and trolley travel. This latter service is recognized as being the most severe encountered in steel mill crane usage and the worm gear is standing up under this abuse in a perfectly satisfactory manner. An important feature of this charging machine is that the use of worm gears permits such an arrangement of gearing and motors as to give the operator an absolutely unobstructed view of the entire charging floor and furnaces.

Carnegie Steel Company (Ohio Works)—Three 160-ton ladle cranes with worm driven main hoist, and two 7½-ton high type soaking pit cranes equipped with worm drives on the hoist, tongs revolving and tongs opening motions.

Carnegie Steel Company (Duquesne Works)—Three 175-ton ladle cranes having a worm driven main hoist.

American Steel and Wire Company—One 75-ton ladle crane, the hoist and travel motions of each trolley being worm driven.

These ladle cranes are all of the four girder, two trolley type. The main trolleys having two drums placed parallel with each other near the center of the trolley, the drum gears intermeshing, thus preventing the load from being dropped in case of breakage of a drum pinion or intermediate shaft. This feature is patented by our company, who has other patents pending on this worm driven trolley.

The cables are reeved from the outside of the drums, thus affording a clearance space under the main trolley for the auxiliary girders and trolley.

The drum pinion shafts are placed outside the drums towards the ends of the trolley, and a worm

gear is mounted near the end of each, the two gears being in line with each other.

The 75-ton crane has one hoist motor which is located between the worm gears at right angles to the drums and shafts. The ends of the motor armature shaft are connected by means of flexible couplings to right and left hand worms meshing with the worm gears. These couplings provide a means of adjustment where by it is possible to so set the gearing that there will be no working contact between the drum gears in the normal operation of the crane, the intermeshing feature being retained only as a safety provision. This adjustment is readily made when installing the motor, is permanent and tends to reduce vibration.

An electric brake is provided on each worm, either brake being sufficient to hold the maximum load.

The upper sheaves are located so as to be accessible from the top of the trolley to facilitate the reeving of the cables.

The construction of the main trolleys on the larger cranes is identical, except that two motors are used, one located outside of each worm gear and the two worms are connected by means of a shaft and flexible couplings. Each motor is large enough to handle the load independently of the other, and in case one is disabled it can be disconnected at the coupling and the hoist operated by means of the other without increasing the stresses in the gearing.

These cranes are all completely equipped with anti-friction bearings. This practice is becoming quite general in the case of steel mill cranes, principally on account of the decreased maintenance charges following their use. A crane equipped in the usual manner with bronze bushings requires frequent lubrication and such bearings are difficult to seal against oil leakage and dirt entrance. Anti-friction bearings are readily sealed and require lubricating attention only at long intervals.

When anti-friction bearings are used particular care should be taken to preserve alignment. On the cranes above mentioned this is done by boring the bearings in line at one setting and by using flexible couplings and self-aligning bearings where there is a chance of misalignment due to deflection or other causes.

No complete test reports on power consumption are as yet available. However, electric power is usually a by-product of a steel plant and the economies in its consumption effected by the use of anti-friction bearings is in most cases of no great importance. It would appear however, that in many cases the size of the bridge and trolley travel motors could be decreased under that usually required for plain bearings. Tests made on the erecting floor of our company show that a force of 10 pounds applied at a radius of 12″ on the armature shaft of the cross travel motor was sufficient to put into motion the completed 175-ton trolley.

The effect of the friction at the sheaves in the case of ladle and other cranes having a large rope reduction, is sometimes overlooked. This friction in addition to the power required to bend the cable around the sheave, builds up the cable load by a certain percentage of increment at each pass, so that the stresses in the lead lines to the drum are appreciably greater than those at the opposite or dead end of the cable. This condition is relieved to a considerable extent by the use of anti-friction bearings in the sheaves.

Indications point to a more extended use of both anti-friction bearings and worm gearing for steel mill cranes, particularly in reference to ladle trolleys, where their use permits a more simple and accessible design, compensation for mis-alignment due to deflection and a known and uniform distribution of loading to all parts, resulting in an absence of unknown stresses due to such causes.

The excellent results which these cranes are giving indicate that our company, who first developed the four girder ladle crane and the interlocked gear type of ladle trolley, have made another valuable contribution to the steel industry.

In conclusion as we have stated, we have approximately 150 of these trolleys in satisfactory operation. We have 40 in the western district and about 30 in the Chicago district. The opinion of any of the mill engineers in the Chicago district will probably be more convincing as to what results they have obtained in maintenance.

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*New Stripper for Inverted Molds**

By F. H. BARNARD*

The subject we present to you this evening is the overhead stripper recently developed for stripping the big-end-up type of ingot from the mold. This ingot is also called the inverted or hot top type.

Stripping of ingots is one of the many critical points in steel making. However, in recent years it may have been elevated to the class of minor evils due to the fairly high efficiency of the modern electric stripper when stripping standard molds. A very brief history of the stripping of ingots may be interesting to you, especially so since there seems to have been somewhat the same progression of ideas and applications to the stripping of inverted molds as was the case with standard molds.

So far as we can recollect, the first type of so-called ingot stripper was known as the core barrel pusher, consisting simply of a mechanism whereby the molds were laid in a horizontal position, or at some angle from the horizontal, and the ingot pushed out with an hydraulic ram.

This stripper was a step in the right direction, but it was found that the machine required unnecessary handling of the ingots and molds. In order to speed up production and do away with this unnecessary handling of molds the overhead hydraulic

*The Morgan Engineering Co., Alliance, Ohio.
†Presented before Chicago District Section, Chicago, Ill.

stripper was developed. As most of you are aware, this type consisted of a stationary hydraulic stripping mechanism which answered the purpose for the time being, but did not make a very flexible outfit, as there was no lateral movement whatever to the mechanism. The same type of hydraulic stripping mechanism was then combined into a movable trolley located on a stationary bridge. With this type of trolley it was possible to place the empty molds on cars on the adjoining track. The succeeding development was the same movable trolley placed on a bridge having longitudinal motion. At this stage the machine possessed the essential motions of the modern stripper; however, it was a maze of universal joints and squirting water.

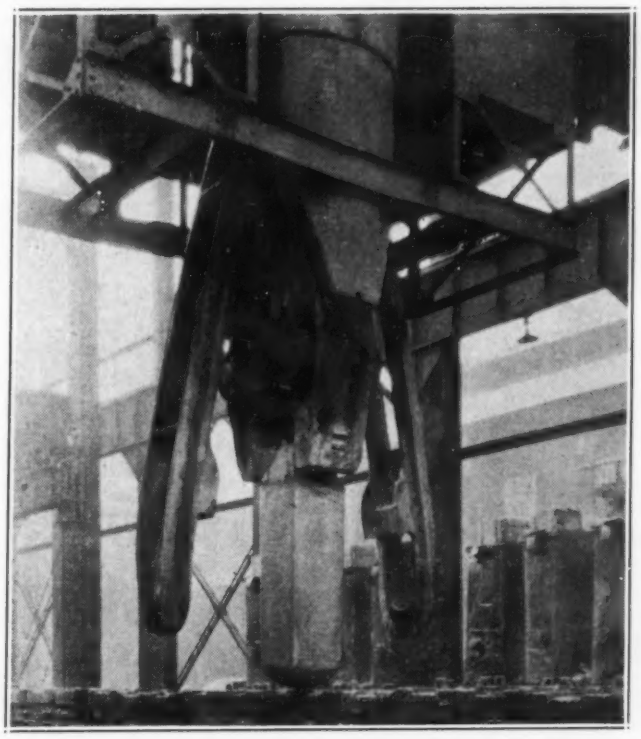

FIG. 1.

In the meantime the electric motor had been developed and we then brought out our motor-driven screw type ingot stripper, the first machine being built in 1899. It may be interesting to know that the first screw type stripper built in 1899 is still in operation.

Most of you are well acquainted with the design and operation of the Morgan screw type stripper for standard molds. There is a similarity between this machine and the overhead hot top type stripper to a great degree in design and only to a slightly lesser degree in mechanical operation.

The screw type stripping mechanism on the standard machine consists of a nickel steel screw with right and left hand buttressed threads which are cut on the lower end of a square shaft. The square shaft extends through and slides vertically in a sleeve which is actuated by the stripping motor located on top of the trolley. These right and left hand threads operate two bronze nuts, one being connected to the ram, the other to the links. The links are operated by four drums, two of which are used for closing and hoisting—also for hoisting or lowering with links closed. And the other two drums are used for opening and hoisting, or—lowering with links open. A clutch manipulated from the operator's cage is used for engaging either the opening or the closing drums. The opening, closing and hoisting are taken care of by one motor.

When stripping, the stripping mechanism is lowered over the mold, the links being engaged with the mold and then hoisted. In case the ingot is not a sticker the mold hoisted from the ingot and placed on to cars on the adjoining track. In case the ingot proves to be a sticker the mold is lowered back onto the car and the stripping motor is started, which lowers a bullnose attached to the end of ram onto the ingot. The mold is then automatically pulled off of the ingot, no stresses from the stripping mechanism being transmitted to the hoist motor or onto the car underneath. There is an alternate method often advocated and sometimes used, which consists in lowering the end of the ram onto all ingots as the

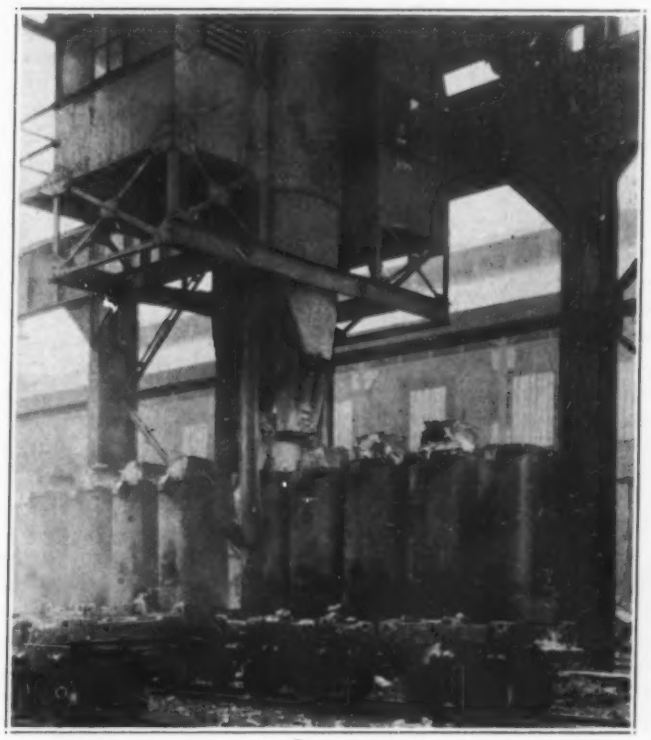

FIG. 2.

initial part of the stripping operation. A distinguishing characteristic of this machine is that the full power of the stripping motor is used to pull the bullnose out when it sticks in a soft ingot.

The foregoing is concerned primarily with the stripping of standard molds.

It must be understood that on both types of strippers the weight of the stripping unit is counterweighted in order to lessen the operating load on the motor ,and to prevent slackening of the cables which might cause the ropes to come out of the sheaves. The effect is also to speed up the stripping cycle.

Within the last few years a large number of steel plants have adopted the mold with the large end up for making certain classes of steels, using hot tops when pouring. This type of mold presented an entirely new problem in stripping, which could not be

done on a standard overhead stripper. As a consequence a logical reversion was made to first principles. When the ingot could not be picked out, the molds were bumped in the hope that the mold would drop off. This method often resulted in excessive breakages on pit cranes, molds, stools and cars.

Later, a stripper was developed of the floor type, wherein the mold with the ingot in it was placed onto this stripping mechanism. The links would engage the ears on the bottom of the mold, holding the mold firmly while the ingot was pushed up. One motor actuated all motions. This type of machine was a step in the right direction, but the use of it necessitated excessive handling of both molds and ingots, and it would not strip all types of molds. The limitations of this machine led to various experiments toward the development of a machine which would lessen the time element in stripping this type of mold, as it was found very desirable to have a machine which would pull the ingot out without the necessity of removing the mold from the car. After a great amount of experimental work, we have developed and installed a stripping mechanism which very successfully accomplishes this result. We have two of these units in operation and in the very near future additional installations will be made.

Unfortunately, our model of this stripping mechanism is not yet completed. It will be exhibited at your June Convention in Pittsburgh. We have, however, several enlarged photographs of this machine taken while stripping a heat.

This stripper is combined with the overhead type and consists of a pair of links very similar to those used on standard molds, with the exception that these links are longer and are provided with lugs for holding the mold firmly to the car. A pair of tongs with gripping jaws are provided, which are located, and open and close, at right angles to the holding down links. These tongs are operated by the same type of screw mechanism as is used on the standard stripper, with the exception that the threads are reversed, in this way providing a gripping and pulling power on the ingot up to the full capacity of the stripper, which to this date has been developed for 150 tons.

To strip an ingot the sequence is this: Close the holding down links into the mold, these links being operated by the four drums in a similar manner to those on the standard stripper. The screw is then revolved in the hoisting direction and, as the tongs are actuated through the medium of a tapered crosshead, the hoisting of the screw will automatically close the gripping jaws. It is then possible to transmit the full power of the stripping motor into the gripping tongs. After a firm hold is obtained on the hot top the tongs will then raise the ingot in the mold. After the ingot has been loosened in the mold the screw is reversed, thus opening the gripping jaws. The holding links are then opened and the machine is in position to strip the next mold.

The resultant force exerted by the bits on the hot top varies with the amount of gripping and hoisting effort transmitted through the bits to the hot top. When the initial grip is made, the upward pressure angle is only a few degrees from the horizontal.

The penetration of the bits varies, of course, with the carbon content of the ingot and the temperature at which the ingot is stripped.

It must be definitely understood, however, that no lifting force is applied until after a gripping force has been exerted on the hot top. In the case of a sticker this gripping force increases as the lifting force is applied, that is—when the capacity of the machine or 150 tons is applied to lifting the ingot out of the mold, the ingot is being gripped by a force of more than 150 tons and at a pressure angle upward of approximately 26 degrees from the horizontal.

This stripping unit, in most cases, can be added to any Morgan screw type stripper now in use. One stripper is now in use with this substitution of stripping units. By carrying two stripper units, one for the inverted type mold and the other for the regular mold, the same stripper in some cases can be used for both purposes, the time necessary for changing the units requiring approximately two hours, as in changing units it is only necessary to lower the stripping mechanism by its hoist cables, connect the same cables to the new unit, and hoist it into position.

From observation made on the stripper units of this type now in operation, it has been proved conclusively that the full power of the stripping motor is applied to the hot top in such a way as to prevent slippage. In several cases of stickers the hot top has been pulled completely off and in other cases the motor has been stalled after the slip gear had been tighetened up so that the full power of the motor could be transmitted. In another case a sticker was found which the machine could not strip. The mold was turned over and an attempt made to strip it with a standard stripper which could not be done.

It is the practice in some plants to remove the clay or tile hot top as much as possible before the stripping operation. This usually consists in breaking that portion of the tile along the side of the heat, but leaves a percentage of the tile on the sides which must be engaged by the gripping jaws. This condition offers no practical difficulty as the gripping jaws crush the remaining tile wall and penetrate to the ingot with full gripping power .

On one of the standard strippers built in 1916, the new unit for stripping hot top type ingots was installed last year. The hoisting speed of this machine is 27 F. P. M., and the stripping speed is 7 F. P. M. Repeated checking of the time required to strip a heat of from twenty-two to twenty-four ingots shows that this stripping operation requires from twelve to fifteen minutes with an operator of average ability on the machine.

Our latest stripper installations provide a hoisting speed up to 75 F. P. M., and a stripping speed of 9 to 10 F. P. M.

We believe it can be safely said that a machine of this type with the stripping speeds now being used can strip a heat at the rate of one ingot in thirty seconds. This, we feel, is very conservative and a good operator would, undoubtedly, cut this time somewhat.

Summing up briefly, the advantages of this ma-

chine are: It is an overhead type. It accomplishes the stripping with a minimum of time and motion, permitting the ingot to be placed in the pit with a smaller loss of heat. It is not necessary to remove the mold from the car. It is adaptable to large scale production.

Safety First

By JOHN M. GULL*

"Safety First" is not a mere Slogan to be used by the careless and indifferent man or woman in a haphazard way.

This Slogan has a real meaning to the person who seriously thinks and honestly works for Safety. The words "Safety First" seriously effect your life and my life alike. The words should be applied in our daily walks of life in the mill or at our homes. Self protection is the first law of nature and he who fails to apply this law or fails to apply the faculties that God provided him with for his guidance must pay the penalties in a full measure. There is no escape from paying up in full for the disobedience or failure to use the faculties you were endowed with at the beginning of your life.

Every form of life that lives and breathes has been provided with some means of detecting danger. The common angle-worm; one of the lower forms of life, has been provided with sufficient intelligence to protect itself under its ordinary and natural way of living. It burrows in the earth deep beneath the sod where it remains hidden from its enemies, the birds. There it remains during the daytime in security. When the day draws to its close and darkness comes on and while the song of the birds is stilled by sleep, the angle-worm known to the fisherman as the night-crawler, becomes active and silently emerges from his hiding place beneath the sod and enjoys himself while his enemies are asleep. The common cut-worm that plays hob with newly set out vegetables and flower plants is endowed with the faculties of self-preservation, so much so, that as he comes forth from the ground where he has kept hidden from his enemies during the light of the day, (so that they cannot feed upon him) to attack your cherished plants and after he has fed upon, generally your most choicest plant, this fellow returns to his hiding place, pulling a piece of the green leaves of the plant after him to close up the hole through which he entered the ground, leaving no trace of his whereabouts for his enemies to find.

Truly, self protection is the first law of nature to all life alike. If it were not so, all life in time would become entirely extinct. The human family has been more fully equipped for self-protection than any other form of life. There is no limit to which human intelligence can attain. Oceans extend over half the globe, their liquid plane through which no path appears, but there the skill of man, coupled with his intelligence, can build his strong knit bark and make the tractless deep a highway through the world. The raging torrent rolls its waters to the main and as it dashes over the mountain cliff, the human hand can withdraw it from its course and render its power subservient to his will. True, we can not arrest the sun in its course and have perpetual summer all the year, but by the use of the intelligence that we have been endowed with, we can build and fabricate, we can store away so that we can sit by our fireside while the elements maintain their fiercest war without. We have been able in the last few years to conquer the air in a large measure, sailing over the frozen miles and miles of storm and ice fields, and we have even crossed the pole. We have been able by using our intelligence to sail deep beneath the ocean wave, and to talk to friends in other countinents, thousands of miles from home by the use of the wireless.

Truly, man was created Lord of all he surveyed. Man is not a mere animal, he is a creator and he surely is able with his tremendous power of creation to ward off accidents if he wills so to do. The trouble with the human family today is that we have sorely failed to use our faculties for self protection. We are depending upon someone else to look after our safety. We depend upon traffic signals to guide us to safety rather than to use our own brain and eyes. Nature's God, after he has bestowed upon any form of life functions for their well being, will not permit of the disuse of such a function. Refuse to use your eyes, your arms, and your legs, your mind or your brain and nature's God will take such functions away. They will become so dulled and dwarfed that their use when you need them most is of little value. It seems to me preposterous to think that man who is so fully equipped with a brain as to conquer the raging torrent, he who can harness up the lightning streak that flashes through the heavens and apply its power to his use, he who has conquered the ocean's wave and its angry storm, he who can sail through the heavens with more speed than the American eagle, and can speak to friends in far off continents, should be balked in the matter of preventing accidents.

This work must begin with the education of the child, it must be taught that self protection is the first law of its being and that to live to a ripe old age it must keep the faculties it was given at birth fully active and alive and quickened by use. At the steel plant we are handicapped by the fact that all employees are of the age when their habits of life have been formed and their ways of work are set. This requires hard unremitting toil to the man who has to teach them how to protect themselves. An old dog is hard to teach new tricks. This is just as true of the man up in years; he also is hard to teach new methods of working along safety lines. A German contractor's attention was called to a de-

*Chief Safety Inspector, National Tube Co., Lorain, O.

fective and unsafe ladder by one of his laborers who was carrying a hod filled with brick to the second story of a building. The contractor looked at the unsafe ladder and replied, "Oh, go ahead up, I risk him." This spirit of safety first is, I am afraid, the spirit of too many men, who often say my motto is Safety First, but who show by their actions that they have little regard for the motto deep down in their hearts. Safety First, to be 100 per cent is a matter entirely of education. It should be started in the schools when the minds of the pupils are easily controlled; it should be their most important study. It should be the noblest duty of the school boards all over the world to teach the children how to live right to preserve their health and to look out for their safety. The states should see that young men and young women when they are graduated from their schools and colleges and are about to seek situations in the industrial world are equipped with an education along safety lines so that it will not be necessary for them to depend upon others to look out for their safety every moment of the day.

Safety first means, use your own faculties, your own eyes, your own ears, don't depend upon some other person. He might fail you at some critical moment and this, no doubt, would mean an ambulance call and sorrow for your friends as they drop flowers on your grave.

Some time ago I was the owner of a small fox terrier dog. I called him "Sandy." He became one of the best pals a man would wish to have. While only a dog, "Sandy" was true to his natural instincts or faculties that were given to him at his birth, and which grew stronger as he grew older.

Sandy loved me as only a dog can love his master. I have often thought that if I could love my God as Sandy loved me, I could also reach Heaven as Elijah did in the fiery chariot. Sandy placed all his confidence in me until I played a joke on him. He would catch tid bits of food which I often threw to him, until one day while tossing him bits of food I suddenly switched the food and in its place threw him an old well worn chew of tobacco which he caught and spat out just as quickly. From that day to the day of his death Sandy refused to catch any food thrown by me to him. I had fooled him and lost his confidence. After this he wanted first to smell what I threw. He never lost confidence in this faculty, which was given to him at birth for his self protection. This faculty had never fooled him, he knew he could trust it to the utmost limit. The hog is considered a dirty, filthy animal, and correctly so. He also is gifted with faculties at his birth for self protection that became stunted and dwarfed due to no causes that he contributed to himself. He enjoys good, wholesome, clean food, and fresh, clean water just as much as you or I, but he has been raised under environments and conditions that would also make a hog of you or I if we were brought up the same way. As a general rule he gets nothing to eat but the scraps that are thrown in the filthy garbage cans and the remains of dead animals from the slaughter houses; if on the farm where he is raised there happens to be some old watery bog containing nothing but putrid water and slimy mud this place is selected for him, and fenced off so he cannot get away. He is forced to drink this contaminated mosquito-infected water and use it for his bath while he seeks relief from the hot sun and the stinging bites of poisonous insects. All this is forced upon him, he has no way of escape.

The human family has made the hog just what he is and the old expression you have often heard, "root hog or die" has a world of meaning to the hog. With him it becomes a fact indeed. For his personal safety and to even exist in a meager way, this old saying becomes only too true. He must root, hog, root, or he will die; he has no choice, so he becomes dirty and filthy due to the treatment he gets from the human family. Safety first to the hog is just as serious to him as far as his life is concerned as safety first is to you or me, as far as our lives are concerned. I will make no mistatements when I say that if the hog could select his food and his mode of living, he would use the faculties that he was given for his self protection and would in a large measure out strip thousands of the human family in a sanitary measure and he would be more like the perfect hog that God created, than the human being would be like the perfect man or woman that God also created. The animal will live according to his instincts when he can. The human family will not do so. We form many habits and create within ourselves false appetites and desires that seriously effects our personal safety and the safety of the children that follow us by our disobedience to the natural laws, and as we see the serious results by doing so we foolishly ask ourselves, "what must we do to be saved." The answer is simple, use the faculties you were given at your birth for self protection, cultivate them to their fullest capacity and your reward will be a long and useful life, one free from accidents and sickness. Use your head.

As I stated previously it is hard to teach old dogs new tricks, and as old employees are numerous in the various mills and factories, their safety education must be forced upon them, whether they will, to accept it or will, not to accept it. While teaching the old dog new tricks often it is necessary to punish him in order to make him obey and perform. This same rule applies to teaching old hands at the mills and shops, it often becomes necessary to mete out to certain individuals some method of punishment to have them perform their duties in a safe way; in fact, this punishment is necessary only too often. The Safety Department in order to be 100 per cent, must have the full support of every executive head in all departments. Full co-operation is necessary. The various foremen must be sold on safety 100 per cent, and he also must be supported by the executive heads of his department from the manager on down the line to his general foreman. While instructing the workmen the foreman must not allow any friendship to interfere with men he has instructed. All must be made to comply with their safety instruction and penalized alike for their failure to follow such instructions. We are having considerable success at the steel plant in the reduction of accidents during late years. This is entirely due to educating the foremen and worker alike to their requirements. Our methods have the full suport of the manager and his superintendents. All executive heads are working in harmony and co-operating with their

foremen, which is showing good results. We are getting better all the time, and hope to continue this work until all of our accidents are practically eliminated.

Industry is rapidly becoming mechanical, and with mechanical production and mass production, the hazards become more severe every day. In the process of evolution the survival of the fittest has been the survival of the safe.

The Safety movement has been a religion to those who are giving their lives to it. Safety consists quite as much in knowing how to face dangers as in avoiding it. Safety in Industry has turned out to be immediately correlated with efficiency. Safety has turned out to be immediately correlated with alertness and intelligence. Accidents are stupid. It is the untrained, unalert one who is injured.

Carelessness is one of the most contageous diseases in America today, and at the present rate of increase it will soon be one of the most fatal diseases. We have been able to place guards over all dangerous exposed parts of machinery, and we have done all this at the steel plant. Our only trouble is that we can not place guards over the minds of our men.

Visit the hospital where injured men are recovering from their hurts. I venture to say that 90 per cent of them will tell you that when he was injured he was thinking about something else at the time of the injury besides his safety, and that his mind was not on his job when injured. We must be trained in careful habits and that is no task for a kindergarten teacher. To guide men whose habits are more or less firmly fixed requires patience, tact and resourcefulness. Chance taking must be eliminated by getting together and seeing to it that we all do our part in eliminating this waste of time lost through accidents. It can be done. You should do your part in this work of humanity?

Items of Interest

Mr. Charles G. Dent, formerly Superintendent of the Hot Mill at the Ambridge plant of the Spang Chalfant, Inc., has been made General Superintendent of the Ambridge plant.

William H. Warren, one of the most widely known executives in the Iron and Steel Industry, was recently elected Vice President in charge of operations of the Lukens Steel Company at Coatesville, Pa. Mr. Warren was formerly General Superintendent of the Lukens Steel Company, and his many friends in the industry are congratulating him on his new capacity.

J. H. McElhinney, an active member of the A. I. & S. E. E., formerly Assistant General Superintendent at Lukens, has been made General Superintedent to succeed Mr. Warren. The membership of the A. I. & S. E. E. are glad to extend their congratulations through the Iron and Steel Engineer.

Donald B. Spackman, formerly in charge of the Forging Departments of Lukens, has succeeded J. H. McElhinney.

M. E. McGrail, Mechanical and Electrical Engineer at the Columbia Steel Company at Butler, Pa., has resigned to accept a similar capacity at the Great Lakes Steel Company, at Ecourse, Mich.

Gordon Gage, Electrical Superintendent at the American Rolling Mills Company, at Middletown, O., has been transferred to the Columbia Plant at Butler, Pa. Mr. Gage will be Electrical and Mechanical Engineer at this plant. He is an active member of the A. I. & S. E. E. and his host of friends are extending their best wishes through these columns.

Fred Madden, formerly with Westinghouse Electric & Mfg. Co., is now associated with the E. A. Lundy Co., located at Fulton Building, Pittsburgh, Pa.

Herbert W. Young, President of the Delta Star Electric Company of Chicago, returned from Europe, August 6 on the Olympic. While abroad he visited electrical equipment manufacturers in France, Germany and England.

W. J. Beck, for 19 years director of research of the American Rolling Mill Company, has been appointed assistant to Charles R. Hook, general manager. Mr. Beck will have direct charge of the development in electrical steel sheets for magnetic purposes. He is widely known in this branch of the industry, having joined Armco in 1903. Graduating from Purdue University in 1896, he was for several years an electrical engineer with the Westinghouse Electric & Mfg. Co. He came to the American Rolling Mill Company as superintendent of the electrical department and in 1910 was appointed director of research.

Charles R. Barton, for the past several years vice president in charge of the seamless tube mill of Spang, Chalfant & Co., Inc., at Ambridge, Pa., has been made vice president in charge of all operations of that company.

Grover C. Brown, chief civil engineer at the Cambria plant of the Bethlehem Steel Company, Johnstown, Pa., has been appointed Management's Representative at that plant. He succeeds C. L. Baker, who has been transferred to the company's Lackawanna, N. Y., works.

At a recent meeting of the Electric Furnace Section of the National Electrical Manufacturers' Association W. D. Little was re-elected chairman and R. F. Benzinger, secretary. Both are executive members of NEMA, the former being associated with the Hoskins Manufacturing Company, of Detroit, and the latter with the Electric Furnace Company, Salem, O.

ADVERTISING PAGES REMOVED

C. L. Baker, Management's Representative at the Cambria plant of the Bethlehem Steel Corporation for more than six years, left this plant, effective the first of August, to assume charge of the industrial and public relations of the Bethlehem Corporation at its Buffalo works.

Mr. Baker has been connected with the steel game for more than 25 years and during that time has served in various capacities. After graduating from Ohio Northern University, Mr. Baker entered the service of the Carnegie Steel Company, his first connection being at Donora, and later he was with the Carnegie interests at Pittsburgh, being with that company for 10 years.

He went to Johnstown in January, 1913, as Chief Clerk of the Accounting Department and when the Comptroller's office was moved to Philadelphia in 1915, Mr. Baker was advanced to the position of General Chief Clerk in charge of all accounting work in Johnstown. Later when the Union Coal & Coke Company was acquired in Washington County, all of this operation was placed under his jurisdiction. He continued in this capacity until March, 1923, when the Bethlehem Steel Company assumed control of the Cambria Steel Works, at which time he became Management Representative in charge of industrial relations. His new duties at Buffalo will be along similar lines.

Mr. R. C. Lawrence has resigned his position in the Engineering Department at the Youngstown Sheet & Tube Company at Youngstown, O., to accept the position of Contract Engineer in the Electrical Research Products, Inc., subsidiary of the Western Electric Company, with offices located at Hawthorne Station, Chicago, Ill.

The Holophane Company, Inc., of New York are distributing a new booklet No. 900 entitled Ornamental Luminaires. It contains various suggestions as to types of lighting fixtures to be used in various structures. Copy may be had on request.

A new 112-page catalog No. 16 on Electrical Measuring Instruments has been prepared and is now ready for distribution by the Jewell Electrical Instrument Company of Chicago. Copy supplied to interested parties on request.

A new bulletin 110-B on Clark "3C" Push Buttons is now obtainable. This bulletin supersedes Bulletin 110-A and a copy will be mailed to you by writing to Clark Controller Company, Cleveland, O.

The Clark Controller Company of Cleveland have issued a new 22-page Bulletin No. 114 on Vari Time Magnetic Controllers. The bulletin is very complete and well illustrated and will be sent on request.

The Martindale Electric Company, at 1256 West Fourth street, have just received from their printers their No. 14 general catalog which shows their complete line of Martindale Electrical Maintenance Equipment, including Martindale Commutator Undercutting and Slotting Equipment.

Heretofore, they have always shown their Undercutting and Slotting Equipment separately in their No. 9 Catalog. The No. 14 consolidates or shows the complete Martindale line.

C. L. BAKER

OIL PURIFIER LEAFLET

The Sharples Super Centrifuge Oil Purifiers are discussed in leaflet No. 20240C recently released by the Westinghouse Electric and Manufacturing Company. The applications, features, operation, and construction of the units are explained in a concise manner. Included in the leaflet are various illustrations showing construction and application of the purifiers. The units may be obtained at capacities from 180 to 1200 gallon.

BETHLEHEM STEEL CORPORATION ACCIDENT PREVENTION RECORD

Last year was the most successful year in the company's history in the prevention of accidents. Lost time due to accidents was reduced 24.2 per cent; the number of accidents was reduced 28.4 per cent, and the number of fatal accidents was reduced 34.2 per cent—notwithstanding a rate of operations for the year higher than in any year since 1917.

It is estimated that the year's results amount to a saving in wages to Bethlehem employees of more than $750,000.

The accomplishment represented by these results is attributed to the whole-hearted co-operation of the employees and the management in the accident prevention contest begun early in 1928. The year's results marked further substantial progress in preventing accidents which over a period of ten years have been reduced more than 63 per cent.